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THE ASTORIA CITY WATER-WORKS.

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WITH DISCUSSION.

It is an attractive feature of the engineer's vocation that each engagement presents for solution new and often interesting problems which tax both skill and ingenuity, and it is seldom that the results, when carefully observed and properly recorded, are not of both interest and profit to others in the profession. The author proposes to make brief mention of the old water-works of Astoria, Ore., and to present a description of the works just completed, and to accompany it with such notes and observations incident to construction, cost and final determination of results as many engineers in charge of work record in their private note-books, but, at the expense of the profession at large, often fail to make a matter of public recital. In the amount of expenditure involved these works are in no way exceptional, but in variety of work and consequent interest, it is believed that they have not been often exceeded, even by works of considerably greater magnitude.

The Old Works.

The city of Astoria, first established in 1811 by John Jacob Astor, and made memorable by Washington Irving's "Astoria," is situated on the south shore of the Columbia River, here 7 miles in width, about 12 miles above its mouth, and occupies a much broken peninsula rising to a height of 600 ft. between the Columbia River and Young's Bay.

In 1883–84, the Columbia Water Company, a private corporation, built a system of works utilizing Bear Creek, a small mountain stream flowing into the Columbia about 7 miles above the town, as a source of supply. The water was conducted by gravity to the town through a line of lap-welded wrought-iron pipe of the following sizes and lengths: 1 825 ft. of 10-in., 2 275 ft. of 8-in., 59 000 ft. of 6-in. The line terminated in a reservoir of 500 000 galls. capacity built at a flow-line elevation above mean low tide of 166 ft., from which the water was distributed over the town through pipes ranging in size from 6 ins. to 1 in., the smaller sizes largely predominating. No provision was made for fire protection from these works. No especial interest attaches to them other than as showing a remarkable example of how works may be built by so-called practical men without incurring any expense for engineering supervision; 140 000 galls. in 24 hours is all that the pipe-line could ever be made to deliver into the reservoir, not over 60 or 70% of what might reasonably have been expected if properly built. The line was laid from the source immediately to tide water in the Columbia, without recourse to instrumental work, and thence down the tide flats to town, thus subjecting the entire line to the greatest pressure possible, and to the destructive action of the salt water, which in the course of a very few years so thoroughly honeycombed the pipe as to render it a very serious question from day to day whether or no water could be supplied to consumers on the morrow. In addition to this the pipe was laid without regard to either alignment or grade, and with so little cover that the lateral components of the thrust at sharp angles frequently pulled the joints entirely apart.

This train of evils consequent upon stupid work led in 1891 to an agitation on the part of the citizens which culminated in the appointment by an act of the State Legislature of a Board of Water Commissioners, authorized to purchase the works of the Columbia Water Company, to reconstruct the same, or to build new works with a view

to greater efficiency and supply, and to issue municipal bonds in an amount not exceeding $500 000 necessary for the accomplishment of these ends.

Shortly after its organization, the Commission purchased the old works for the sum of $75 000. Some effort was then made to secure an improvement of the service without resorting at once to entire reconstruction, but without any satisfactory results being attained, while repeated interruptions in the water supply by failure in the gravity line, the insufficiency of the supply, and the inability of the system as built to afford water to any of the higher elevations of the city, all rendered apparent the necessity for speedy construction of new works.

The New Works.

In November of 1893 the author reported for the Commission on an increased water supply, and recommended the construction of a new system substantially as has been subsequently carried out. During the following spring a beginning was made on the preliminary surveys and plans, but the general business depression of 1893 influenced the Commission to suspend operations indefinitely. In July, 1894, however, matters were again taken up with the intention of getting construction under way the following spring. In order to meet in a measure the pressing public demand for more water pending the construction of the new works, the old gravity line was parted at tidewater elevation, about 8 000 ft. distant from the reservoir, and diverted into a tank, thereby securing about 160 ft. more fall in the pipe line and an increase of one-half in the discharge. From the tank the water was pumped to the reservoir by arrangement with the electric street railway company to supply the power. The plans for the new works were completed and the programme for construction carried out as previously purposed.

Water Supply.—The water supply is derived from Bear Creek, the diversion being made about 1 mile farther up the stream than was selected in the construction of the old works. This is a beautiful mountain stream having a drainage area above the diverting point of 4.82 square miles, all of which is heavily timbered and covered with a dense growth of moss and ferns. During the rainy season the run-off varies from 10 000 000 to 30 000 000 galls. in 24 hours, and the dense vegetation serves to retain and prolong the supply during the few

weeks of dry weather in August and September to an extent very unusual in a stream having so limited a drainage area. The yield of this area was materially increased by diverting into Bear Creek above the head works another stream, Cedar Creek, which originally entered a mile farther down, this work being accomplished at almost no expense. Careful weir measurements of the flow of the stream during the lowest stages show the following results:

1890.........	5 118 000 galls.	in 24 hours	below	mouth of	Cedar Creek.
1891.........	4 763 000	"	"	"	"
1892.........	4 280 000	"	"	"	"
1893.........	2 646 000	"	above	"	"
1894.........	2 400 000	"	"	"	"
1893.........	718 000	"	in Cedar Creek.		

From these results and because of the ease with which about 50 000 000 galls. can be stored just above the diverting weir, it was assumed that a daily supply of 4 000 000 galls. could be made available from this source with a reasonable degree of certainty. It was accordingly determined that this figure should be made the basis for all computations of capacity in the new works. The construction of the storage reservoir was, however, to be deferred until the demand for a supply in excess of that afforded by the stream direct should necessitate its construction. This determination as to capacity in the construction of the new works was also influenced by the rapid growth of the town, now having a population of fully 10 000, and by the fact that the large and available sources of supply for the future city will all be brought in over the same general route adopted for the new line.

General Arrangement.—Briefly outlined, the new works consist of the following structures: The head works on Bear Creek, a small masonry diverting weir with a crest elevation of 589.35 ft., diverts the water through a head gate into a small receiving basin, from which it is led through an 18-in. wood-stave pipe to a masonry settling basin 1 000 ft. distant, where it is screened and weired. The water is then conducted through pipes of the following character and order: 11 956 ft. of 18-in. wood-stave pipe, 1 239 ft. of 16-in. riveted steel pipe, 10 450 ft. of 18-in. wood pipe, 2 413 ft. of 16-in. steel pipe, 3 606 ft. of 18-in. wood pipe, 12 776 ft. of 16-in. steel pipe, and 13 082 ft. of 18-in.

wood pipe—in all a little over 10.5 miles, to an elevation within the city limits of 425.75 ft. Thence it passes by a rapid descent through 5 574 ft. of 14-in. steel riveted pipe to the power and gate house at the new reservoir. The elevation of the water surface of the reservoir when full is 282.4 ft., and of the point of power development 289.00 ft. The reservoir has a capacity of 6 250 000 galls. and is located on the Young's Bay side of the peninsula, while the city is situated principally on the Columbia side. From the reservoir the water is conveyed to the distributing system through an 18-in. pipe laid in a tunnel 1 200 ft. long, passing through the divide. The distribution is divided at present into a low and high service, the lower being supplied from the small reservoir previously connected with the old works, and the high service from the new reservoir. These two services, in case of fire, are thrown together, the lower reservoir cut out by the operation of a check valve, and the pressure secured from the upper reservoir. This end is accomplished by the operation of two hydraulic lift gates which are both opened and closed from the central fire station by means of a special hydraulic gate governor designed for this purpose. Two other services of greater elevation will eventually be added, three of the four being supplied by gravity. The fourth will be supplied by pumping with water power at the new power house.

Construction.—It was expected that by letting all contracts for materials and construction during the winter months, the contractors would be able to complete the work during the dry season, usually lasting in this locality from June 1st to October 1st. Accordingly advertisement was made in December, and bids opened on January 10th, 1895. Proposals were invited on the work divided into seven divisions, each being segregated into the different items entering into it, and a percentage of reduction from the aggregate amount of the proposal asked in consideration of the entire seven divisions being awarded to the same person. The divisions referred to were as follows:

First.—Clearing and grubbing the conduit right of way and grading the road alongside it; making necessary bridges and culverts; constructing a telephone line; excavating and refilling the conduit trench, and excavating the reservoir.

Second.—Head works, diverting weir and settling basin.

Third.—Lining reservoir, erecting gate and power house, including the furnishing and placing of all gates, fittings and appliances in it.

Fourth.—Wooden stave conduit, furnishing and laying.

Fifth.—Riveted steel conduit, furnishing and laying.

Sixth.—Distributing system.

Seventh.—Tunnel.

Eighth.—All cement required on the work.

The almost entire absence of construction work on the Pacific Coast at this time rendered the bidding exceedingly spirited, with the final result that the Commission was confronted with the alternative of awarding several important divisions of the work on proposals, which, though formal in the last degree, and supported by contractors determined to have their rights recognized and to secure the work at any cost, were manifestly less in amount than that for which the work could be performed; or on the other hand, rejecting these bids and awarding to higher bidders. The author holds, in the much-discussed question to which this gives rise, that though a private person or company may often, with creditable discretion, discard a bid that is too low, yet in handling the funds of a municipality, if the proposal is strictly formal and the sureties satisfactory, the administrator of such funds cannot with due propriety and proper regard for the wishes of the public whom it serves discard such a bid. The subject has proved an interesting one in Astoria in the light of after developments. After a careful consideration of the matter, the awards were made to the lowest bidder in each case, and divisions 1, 2, 3, 6 and 7 were let in accordance with the above hypothesis, all but No. 6 being united in one award. Nos. 5, 6 and 8 were each awarded separately to different parties. While it was to be expected that some unpleasant conflict of interest would arise from this dividing of the work, yet the large saving to the city thereby was considered amply compensative.

Proposals were invited on $200 000 of bonds at the same time that bids were asked on the construction, but through certain unexpected difficulties in their negotiation, the money was not realized on them until the following May, when the contractors were immediately notified to proceed with the work. In the mean time the contracts for construction had been held in trust by a third party, to be delivered on the mutual consent of the principals.

The delay in getting the work started, and the necessity of ordering most of the steel used in the construction from the East at a time when the suddenly increased demand made it exceedingly difficult to get

orders from a distance filled, caused it to be very late in the summer before work was well started on several of the contracts.

Affairs moved along as smoothly as can be expected on work where the majority of the contractors are losing money, until the middle of September, when the contractor for divisions 1, 2, 3 and 7 suddenly failed, and disappeared to escape the vengeance of some hundreds of unpaid laborers. The customary suits, attachments and injunctions immediately followed. A few thousand dollars allowed on estimates, still in the hands of the Commission to the credit of the bankrupt concern, neither public funds nor public works being attachable in Oregon, were by the order of the court paid over to a receiver. The Italian element, which largely predominated among the laborers, not being satisfied with the slow process of law in the recovery of their claims, and being incited by irresponsible and incendiary agitators, after trying for some days to force the payment of their employer's private debts out of the public funds in the hands of the Water Commission by parading the streets in full force in martial order and by besieging the offices and residences of the members of the Commission and of the engineer, finally inaugurated a strike against the city. Arming themselves with guns, axes and clubs they forced the suspension of all work outside the immediate confines of the town, notified all parties that any attempt to resume, until they had been paid in full, would be at the peril of their lives, and that unless they were speedily settled with, the works already built would be destroyed with giant powder. The Commission resisted the revilings and ill-considered advice of a large but misguided portion of the citizens, and steadfastly refused to incur a single expenditure not legally authorized. In the mean time arrangements were made with the bondsmen of the defunct company to proceed with the work, and public sentiment was satisfied when all strikers were offered work, payment of wages to be made weekly, and guaranteed by the city. As was anticipated, the strikers, misinterpreting these actions, attributed them to fear instead of sympathy, and remained as obdurate as ever, refusing to change their position until all claims for back wages were satisfied. This being impossible, however desirable, through lack of suitable legislation in Oregon, and public sympathy being then largely withdrawn, a determined effort was made to start the work, which was without much difficulty effected by the moral suasion of 25 Winches-

ters. Most of the men returned to work in the course of a few days; but after trying in vain for two weeks to get decent and expeditious work from this element, which, through the influence of agitators and Italian lawyers, constantly maintained a menacing attitude, the author gave up in despair and had the entire force summarily removed from the work, and new laborers employed.

The gravity line was completed, and the water formally turned into the new reservoir on December 21st, in the presence of a large number of enthusiastic citizens. Although this was ostensibly the first water to enter any part of the new work, perhaps it is unnecessary to add that everything had been very quietly but thoroughly tested beforehand; and any imperfections in workmanship, liable to grow into a mountain of difficulty in the eyes of the populace, were well taken care of in advance.

The tunnel was completed on February 22d, and water was turned through from the reservoir into the low-service distribution about February 10th. In the meantime, however, the city had for some weeks been supplied from the new conduit by laying a temporary line of pipe up over the tunnel point and down to the low-service reservoir. The high service is not yet quite complete, as most of the pipe used in it was taken from the upper part of the old gravity line and from the old distribution, which could not be disturbed until the water supply was available from the new source and through the new distribution. The entire plant will have been completed in less than one year, although the larger part of the work has been done during the rainy season, not a light matter where the average annual rainfall is in excess of 75 ins. The prosecution of the work as a whole was very trying to both contractors and engineers. To the former, because only one succeeded in completing his work without sustaining a loss, to the latter because of the extreme difficulty always experienced in enforcing the provisions of a contract under such conditions. By a combination of circumstances, fortunate to the city, the works have been built at a remarkably small cost; and the author doubts if there is another system on the Pacific Coast where similar results have been accomplished with a smaller expenditure.

During construction, daily reports of force, materials used, and progress made on each part of the work, were made to the Chief Engineer; and these have been made the basis of carefully prepared esti-

mates of cost, which are submitted in part with this paper. They may be considered entirely reliable. These reports, by the way, have proved invaluable in unraveling the affairs of the contracting company that failed, and in settling many claims regarding extras, etc.

Head Works.

The diverting weir is located near the head of a narrow, rocky and precipitous gorge on Bear Creek. It is very simple in character, is founded on solid rock, is entirely tight, and serves to divert the water through the head gate into a small receiving chamber, from which it enters the pipe leading to the settling basin, while the surplus water passes on over the weir. The masonry is of rough rubble basalt, quarried in the immediate vicinity, the face stones being squared. The mortar is made in the proportions of two to one of sand and imported Portland cement. The receiving chamber is covered with a frame and trap door securely bolted to the masonry.

The settling basin is located 1 000 ft. below the diverting weir. It consists of a masonry basin 50 ft. long by 8 ft. in width, having an average depth of 6 ft. The water enters at the end, flows the length of the basin, where, after passing through duplicate screens and over a measuring weir, it enters the pipe line, which continues uninterrupted to the city reservoir. The masonry is of the same general character as that of the diverting weir, and is finished on the inside with ½ in. of cement mortar, covered with two coats of asphaltum. The screens are of No. 12 sheet brass, perforated with ¼-in. holes, framed with two 1-in. angle irons, and rest in channel iron guides set in the masonry. They are handled by means of a block and tackle hung from a traveler. The measuring weir is of iron plate, has contractions and is provided with a weir gauge by which the gallons of water passing the weir in 24 hours are indicated on a graduated brass scale mounted on an iron pedestal. The index rises and falls with a copper float operating in a stand-pipe set in the wall of the basin, and communicating by means of a pipe with the water below the screens and above the weir. The entire settling basin is enclosed in a corrugated iron-covered structure. This basin reduces the velocity of flow to a rate that results in the precipitation of all heavy matter, and the screens stop all leaves, moss and fir needles with which the water is heavily charged during the rainy reason. Cleaning the screens, which

is usually accomplished with a piece of square rubber packing fastened to the edge of a wooden hoe, is necessary about twice a day during the wet season in order to maintain a full flow in the pipe line. Provision is made for flushing out the basin from the bottom, and for discharging the surplus waters through an overflow pipe when the screens become clogged, or a sudden rise occurs in the stream. The management of the work on the diverting weir and settling basin was, on the whole, so poor that a statement of the cost would have no especial value.

The Pipe Line.

Development.—The gravity line consists of approximately 7½ miles of 18-in. wood-stave pipe, 3 miles of 16-in. and 1 mile of 14-in. riveted steel pipe. The author was influenced to recommend the use of these materials instead of cast iron by economic motives, involving the consideration of many points, beside the question of first cost; and the wood instead of steel for a variety of reasons, some of which are as follows:

Although there are many examples to the contrary, the author has seen steel riveted pipe of light gauge, designed with a reasonable factor of safety, go entirely to pieces in six years of service. With due regard for proper conditions, on the contrary, he has no doubt that the life of wood-stave pipe is much in excess of that of light gauge steel. Its carrying capacity is very much greater at the beginning, and far more likely to remain practically constant. Its transportation over rough roads is much easier, and the saving in first cost is very great. In this case the saving in first cost over a similar size of No. 12 steel was 43%, and nearly 50% over one of equivalent carrying capacity, 19.15 ins. in diameter. That this advantage, on a basis of equivalent carrying capacity, will be largely increased in the course of years can scarcely be doubted. The cost of any other material would in this case have left no choice with the city but to build a line of much less capacity. The use of the stave pipe will be seen later to have materially influenced the character and details of the location.

Location.—As high a line was located as possible, by following down the divide between the tributaries of the Columbia and Young's River, thus avoiding heavy pressures. The exceeding brokenness of the profile (see Fig. 1) gives some idea of the character of the country traversed, although curvature was very freely used in order to avoid sum-

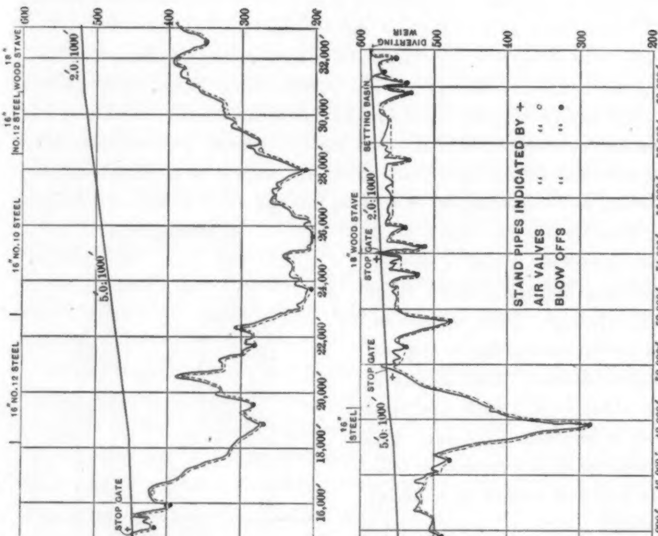
14" NO.12 STEEL
18" WOOD STAVE
16" NO.12 STEEL
16" NO.10 STEEL
16" NO.12 STEEL
18" WOOD STAVE
STOP GATE
10.0: 1000
2.0: 1000
5.0: 1000
RESERVOIR
16" NO.12 STEEL
16" STEEL
18" WOOD STAVE
SETTING BASIN
DIVERTING WEIR
STAND PIPES INDICATED BY +
AIR VALVES " " o
BLOW OFFS " " •

FIG. 1.

mits and depressions, fully 35% of the line being on curves, either vertical or horizontal. The final line was staked from a paper location, laid on a map of preliminary survey having 5-ft. contours. This method was expensive, but unavoidable in securing a satisfactory line, since the entire distance is through forest, windfall and undergrowth of such density as only those familiar with the Pacific Northwest can form any conception of. Here an instrumentman may consider himself fortunate in finding a place where he can see 25 ft. ahead without clearing, and the stranger, supposing himself to be on fallen logs resting directly on the ground, is often surprised when a misstep sends him plunging down 10 or 15 ft. through ferns, brambles, and among rotten logs to the real ground beneath. Half a mile of line a day with a fully equipped party is excellent progress. The expense of such a method of location was well repaid by a saving of about 1 mile in distance over a very good preliminary. In this connection it may be interesting to note that though the country is so rough, the actual length of the completed pipe is but 0.6% longer than horizontal measurement. One of the most annoying features of the location was the difficulty experienced in securing

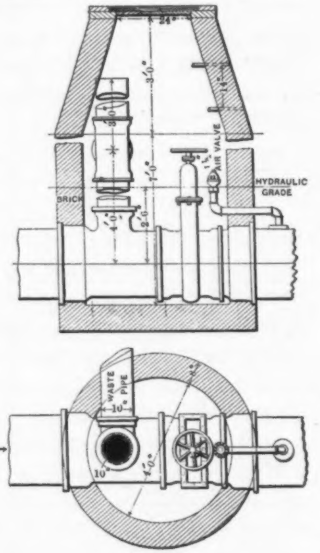

FIG. 2.

the land connections with sufficient accuracy for the writing of deeds for rights of way, since much of the country traversed has been laid out into boom-city additions, with lots of 25-ft. frontage, the work having usually been done in the office, without much regard for even correct external boundaries, which were found in the field in almost every case to be entirely at variance with the recorded plats. Many of these additions had been peddled all over the country, entailing the greatest difficulty in securing a satisfactory adjustment of right-of-way matters. By reference to the profile, it will be seen that the location of the wood-stave

pipe is so made with reference to the hydraulic grade line that at intervals the two approach near enough to permit the use of open stand-pipes (Fig. 2) at these points, while the intervening sections are kept at a lower elevation, causing the pipe to be always full of water, regardless of the quantity flowing, thus realizing the chief essential to long life in stave pipe. At only one point has it been impossible to apply this method, and there the same end is attained by inserting an 18-in. stop gate. By partially closing this when the pipe is carrying less than a full supply, the hydraulic gradient is raised and the preceding summits filled. Danger of over-pressure on the pipe by reckless closing of the gate is entirely removed by the presence on a preceding summit of an open 6-in. stand-pipe. Three hundred feet is the minimum length of radius on horizontal curves, though 60 ft. is frequently employed for vertical curves on the stave pipe.

Pressures.—The maximum pressure adopted for the stave pipe was 150 ft., though this has been exceeded at one point for a few hundred feet, a pressure of 172 ft. being attained. This limit was decided on, not because the stave pipe cannot be made to withstand safely a somewhat greater pressure, but because the author did not wish to depart unnecessarily from conservative practice, and because this was estimated to be about the point of equilibrium in cost between the 18-in. wood and the 16-in. No. 12 steel pipe. The latter was used up to a pressure of 225 ft. head, and No. 10 steel for all in excess, reaching a maximum of 290 ft.

Broken Gradient.—In securing the delivery of the amount of water determined upon, about 4 000 000 galls. in 24 hours, the author adopted the 18-in. diameter for the wood and the 16-in. for the steel, and the incidental broken gradient, in preference to a pipe of uniform diameter, because of the great advantage resulting from being able to use a man on the inside of the stave pipe in the process of building; 18 ins. is about the minimum diameter that can be so handled. The advantage consists in the more perfect rounding out of the pipe to its true form that can thus be secured, and the better inspection of all joints.

Clearing, Road Building and Trenching.—As a consideration for right of way and by special arrangement with the property-owners, the timber and brush were cut for a width of 60 ft., and a 16-ft. road with a maximum grade of 10 ft. in 100 was graded out to the corporate

limits of the city, a distance of 4½ miles from the reservoir. Beyond this limit the clearing was made but 20 ft. in width, and only such grubbing done as was necessary for the construction of a narrow road for the delivery of materials and for the trenching. To avoid heavy work in securing suitable grades for the road, all possible advantage was taken of the elevations of the ground for the entire width of the right of way, 60 ft. inside and 33 ft. outside the city limits, the pipe-line location being crossed and recrossed for this purpose. This method entailed much annoyance, difficulty and expense in keeping the road passable after the trench was opened, since much unexpected delay in the securing of materials made it impossible to have them delivered ahead of the trenching. Any other arrangement in such a country was well-nigh impracticable, however, and would have entailed greater expense than that involved in the plan as carried out.

The trenches were staked out for a bottom width of 3.5 ft. for the stave pipe, being widened to 4 ft. on curves, in order to give the room necessary in springing the pipe into line as built. The depth varied from a minimum of 4 ft. to 22 ft. as a maximum, attained in crossing a few sharp points. For the steel pipe, the bottom width was made a foot in excess of the diameter of the pipe, and in all cases the top width was made uniformly 1 ft. greater than the bottom. The material excavated was generally a yellow clay and argillaceous shale, readily moved with mattock and shovel, with occasional short stretches of very soft sandstone requiring the use of some powder to shake it up. The amount of team work in connection with the trenching, other than for back-filling, was very small. Shoring was necessary at but few places, and at these poles cut on the ground answered the purpose.

This work was a part of that undertaken by the contracting firm the failure of which has already been mentioned, and under its management the road work, clearing, grubbing and nearly three-fourths of the trenching were completed.

Cost.—The contract prices were $50 an acre for clearing, $60 for grubbing, 13 cents per cubic yard for road grading, and 17 cents per cubic yard for trenching, including back-filling.

No especial interest attaches to the actual cost of this work by reason of absolutely incompetent management destroying any value that the figures might otherwise possess. It is sufficient to say that

the cost was greatly in excess of the contract prices. For instance, the actual cost of clearing and grubbing often amounted to fully $300 per acre on a basis of $1 60 per day for labor, while in the trench the men did not average more than 7 or 8 yards a day. The experience of the parties who completed the trenching under the bondsmen of the defaulting contracting firm presents a most forcible example of what efficient management can do, though working at low figures and under most unfavorable conditions. Commencing in October at the beginning of the rainy season, and working much of the time in the mud and rain, this trenching and back-filling was completed at a cost of 17¼ cents per cubic yard with labor at an average price of $1 69 per day, including foreman, nearly 10 yards being moved by each man daily. This cost would have been considerably diminished had there not been much finishing work, very badly scattered, left by the other contractors.

The Wood-Stave Pipe.

Design.—In the design of a wood-stave pipe, the following essential points require consideration: The staves must be thin enough to secure complete saturation and to deflect readily to the degree of curvature employed, and they must be thick enough to prevent undesirable percolation through them. The bands must be of such size that when spaced to secure the desired factor of safety against rupture, there will at the same time be no sensible flexure in the staves and no destructive crushing of the fiber beneath the bands. While fulfilling these conditions, the proportion between the thickness of the staves and the strength and spacing of the bands must be such that the swelling of the wood will not produce injurious strains upon what might otherwise be a properly proportioned band.

The Staves.—The material used for the staves was the native yellow fir. This has been used before for a similar purpose, but the author believes that in each case a much thicker stave was employed. For the Astoria work, the staves were run from 2 x 6-in. stuff with a finished thickness of 1⅝ ins., and twelve staves completed the circle. Lumber wholly free from knots, pitch seams and other defects was specified, and the difficulty experienced in meeting the requirements, especially regarding pitch seams, may be understood from the fact that not over 20% of the lumber sawed from selected logs passed final inspection and went into staves. The outcome was a lot of lumber as nearly

approaching perfection as it is believed has ever been turned out even in the Pacific Northwest. The lumber was about three months from the log when the staves were run, and an allowance of about 2% was made in the width of the staves to allow for seasoning previous to building and for compression in the process of cinching. Staves were run in lots of about 100 000 ft., B. M., as needed, and formed into the pipe with 6 ins. of dirt over it as soon as possible. They varied in length from 12 to 24 ft., and not over 20% were less than 14 ft. in length. They were run with faces true to the circular form of the pipe, with edges on radial lines and a slight projection or bead along the center line of one edge. For pressures up to 80 ft. head, no special attention was paid to the character of the grain, whether slash grain, edge or quarter sawed; but for all greater pressures, while no increase was made in the thickness, only slash-grain staves were used. This action was the outgrowth of observations made on an experimental section. When put under a pressure of 40 lbs. and allowed to remain some days, with an occasional increase by means of a pump to 120 lbs., a few coarse-grained, quarter-sawed staves allowed a perceptible percolation through them at 40 lbs. pressure, and a considerable leakage at 120 lbs. The selecting of the slash-grain staves entailed practically no additional expense, it being attended to when loading at the wharf for delivery on the line.

Bands.—With staves of this character and bands spaced for a factor of safety of about four, it was determined that a $\frac{7}{16}$-in. round band of mild steel upset to ½ in. would properly meet the requirements regarding crushing under bands and flexure in the staves. Eighty-four thousand were used. Steel was specified of a tensile strength of from 58 000 to 65 000 lbs. to the square inch; a limit of elasticity of 30 000 lbs.; an elongation of 25% in 8 ins., and capable of being bent cold and hammered flat without fracture. The following summary of 58 mill tests made by The Osborn Company may be of interest:

	Elastic limit. Pounds per square inch.	Ultimate strength. Pounds per square inch.	Elongation in 8 ins. Percentage.	Reduction in area. Percentage.
Lowest.........	33 550	59 200	23.75	53.50
Mean...........	40 850	62 166	26.21	63.30
Highest........	50 660	63 810	30.00	70.90

The results, as shown by the record of tests and by examination of the broken test pieces, are very satisfactory, but have evidently been secured by the use of high speed in manipulating the machine. Nuts were used about one-fourth thicker than standard. The completed band, before being sent to the work, was carefully coated with asphalt of such a temper and under such conditions that it withstood the great amount of hammering to which these bands were subjected in the process of pipe building without showing any tendency to fly off; and in the accomplishment of this result only one lot of about 6 000 failed to come up to requirements and was recoated. The author has never been able to understand the reason for the difficulty so often reported from the East, in securing an asphalt coating on iron of such temper as to resist shock, and still not rub off in careful handling.

Clips and Shoes.—The tongues used in making the butt joints were of No. 12 B. W. G. steel, $1\frac{1}{2}$ ins. in width and about $\frac{3}{16}$ in. longer than the width of the stave where inserted; they were subjected to the kalameining process to render them non-corrosive.

The saddles or shoes are of the type known as the Allen patent, are made of malleable cast iron of excellent quality, and weigh 10 ounces each.

Strain from Swelling of Staves.—Regarding the last of the requirements for the successful design of wood-stave pipe, that the bands be not overstrained by the swelling of the wood, the author is indebted to D. C. Henny, M. Am. Soc. C. E., manager of the Excelsior Wooden Pipe Company, contractor for this work, for the solution of this matter. Mr. Henny has recently conducted some experiments with very ingenious appliances along this line which are of unusual interest. The experiments consist in making actual measurement of the strains induced in the bands of wooden pipe by the swelling of the staves. For this purpose an ingenious device was designed by Mr. H. Behr, a mechanical engineer of San Francisco. It consists primarily of a very stiff steel spring, resembling a large tuning fork, as shown in Plate I, Fig. 1. A hole is bored through both prongs of the fork near its base, through which the end of the band passes after circling the pipe, the nut being then firmly screwed down. A very slight compressing together of the two prongs, either by tightening the nut or by the swelling of the staves, is magnified at the end of the fork. The motion is further magnified by a simple system of levers and

transmitted to an index hand revolving on an arc. By means of a testing machine this arc has been graduated to conform to different pressures, so that it constitutes a spring balance designed to measure heavy pressures with quite a high degree of accuracy, and with a very slight deflection at the point of applying the load. With a tension of 10 000 lbs. on the band to which the spring is attached, the deflection is but 0.02 in. Two experiments made on independent sections of stave pipe built of kiln-dried yellow fir staves 1⅜ ins. thick, each section being 18 ins. in diameter and 12 ins. long, banded with ½-in. round bands, were conducted in the following manner and with the following results :

Section 1.

No. 1. On February 27th, a strain of 4 750 lbs. was applied and the pipe immersed. The following strains were recorded on succeeding dates :

Date......	March 1st.	March 4th.	March 7th.	March 9th.	March 12th.
Strain, lbs.	3 400	2 950	2 750	2 525	2 525

The final strain maintained between the staves was 153 lbs. per square inch of contact.

No. 2. The band was loosened to the strain indicated and immersed again with the following results :

Date.............	March 12th.	March 18th.	March 21st.	March 26th.
Strain, lbs.......	100	1 500	1 500	1 550

The final strain maintained between the staves was 94 lbs. per square inch of contact.

No. 3. The band was loosened again to the strain indicated :

Date.....	Mar. 26th.	Apr. 1st.	Apr. 4th.	Apr. 8th.	Apr. 11th.	Apr. 16th.
Strain, lbs.	500	1 000	1 050	1 100	1 200	1 225

The final strain maintained between the staves was 74 lbs. per square inch of contact. The staves weighed 18 lbs. dry and 27¾ lbs. after the experiment.

Section 2.

No. 1. The band was first cinched up to a tension of 5 000 lbs., then loosened to the strain indicated, and the pipe finally immersed:

Date........	Apr. 16th.	Apr. 17th.	Apr. 20th.	Apr. 24th,	Apr. 27th.	
Strain, lbs...	450	1 400	1 900	2 000	1 975	
Date......	May 1st.	May 4th.	May 7th.	May 10th.	May 13th.	May 17th.
Strain, lbs.	1 900	1 900	1 800	1 700	1 600	1 600

The final strain maintained between the staves was 97 lbs. per square

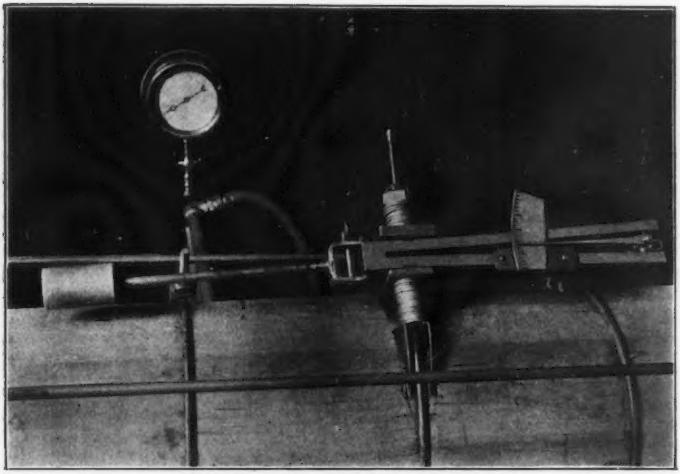

FIG. 1.

FIG. 2.

inch of contact. The staves weighed 28 lbs. when the experiment was finished, and 20.8 lbs. after being kiln dried subsequently.

These results present an interesting study, but, without enlarging on all they set forth, it is plainly shown that the maximum compressive strain the wood can resist permanently is not much in excess of 150 lbs. per square inch. This fact, since the pressure between the staves must considerably exceed the internal pressure tending to force them apart in order to maintain a tight joint, demonstrates conclusively the limit of safe pressure in wooden pipe construction to be little if any in excess of 100 lbs. per square inch under the most favorable conditions with this class of timber. They also show that when the initial strain is very small the swelling of the staves alone is capable of developing a temporary strain of about 125 lbs. per square inch, a fact which will readily account for the frequent bursting of tanks built with thick staves, and small factors of safety. It will also be observed that, while the pressure is largely self-adjusting, whether a large initial strain is applied in back cinching before filling or the bands but lightly cinched, the former practice seems to insure a somewhat greater permanent pressure between the staves and a correspondingly tighter pipe. So far as these results influence the spacing of bands in pipe construction, they need only be regarded when dealing with low heads and wide spacing, the strains then arising from this source being larger relatively to the bursting pressure due to water head than under any other conditions. In close spacing, the strain from this source falls, of course, below that ordinarily allowed for cinching.

The band spacing employed was as follows:

Head in feet.	No. of bands per 100 ft.	Spacing in inches.	Head in feet.	No. of bands per 100 ft.	Spacing in inches.
0 to 25	100	12	87 to 92	282	4¼
25 " 30	110	11	92 " 98	300	4
30 " 35	120	10	98 " 101	309	3⅞
35 " 40	134	9	101 " 105	320	3¾
40 " 45	142	8½	105 " 109	331	3⅝
45 " 49	150	8	109 " 113	343	3½
49 " 52	160	7½	113 " 117	356	3⅜
52 " 56	172	7	117 " 121	370	3¼
56 " 60	185	6½	121 " 126	384	3⅛
60 " 65	200	6	126 " 131	400	3
65 " 68	208	5¾	131 " 137	418	2⅞
68 " 71	219	5½	137 " 143	437	2¾
71 " 75	228	5¼	143 " 150	457	2⅝
75 " 79	240	5	150 " 158	480	2½
79 " 83	253	4¾	158 " 166	506	2⅜
83 " 87	267	4½	166 " 175	534	2¼

Construction.—J. D. Schuyler, M. Am. Soc. C. E., has so fully described the general method of erecting this class of pipe in his paper on the Denver Water-Works* that it is unnecessary to elaborate it here. A few points only are worthy of mention. Yellow fir, being a hard and rather unyielding wood, tight cinching was the invariable practice; no butt joints were allowed to pass unless fully driven home; bands, shoes and nuts were repainted with asphalt or paraffin paint immediately before covering; back-cinching followed erection on the following day, and back-filling to a depth of 6 ins. over pipe as soon after as possible; all openings in the pipe over 4 ins. in diameter, beside the 4-in. open stand-pipes, were made with special castings and oakum joints 7 ins. in depth, while smaller openings were made by bolting on saddles over lead gaskets, and placing two bands over the top.

Since it is a matter of the utmost importance to the success of this class of work that it be not undertaken by an inexperienced contractor, the specifications excluded the bids of all parties not able to submit satisfactory evidence of their skill and experience in the construction of stave pipe under heavy pressures. Proposals were invited, and payment made on the basis of pounds of steel used in the bands and feet board measure used in the staves, the price paid for these items representing compensation in full for all expenses involved in supplying these materials and the erection of the pipe complete, exclusive of fixtures, and the back-filling to a depth of 6 ins. over the pipe. The contract was awarded to the Excelsior Wooden Pipe Company, of San Francisco; and to the large experience and hearty co-operation of the company's efficient manager, D. C. Henny, M. Am. Soc. C. E., is due in no small degree the unqualified success of the pipe-laying. This commenced in the latter part of July under some disadvantages, but by aggressive and capable management the work was hurried through to completion in October before the heavy rains had set in.

Tightness.—A test for tightness was made of the upper 2½ miles of this line shortly after the water was first turned in. This gave results which the author believes have never been surpassed in any other pipe construction of any class. The pipe was filled from the head works, and, the gate at the lower end of the section being closed, the water rose and passed off through the overflow from the stand-pipe immediately

* See *Transactions*, Vol. xxxi, p. 135.

adjoining the gate. The head gate was afterward closed. This gate was not absolutely tight, but permitted the passage of a little trickling stream, not exceeding, perhaps, 1 quart in a minute. The assistant engineer in charge of the work was much surprised on the following day to observe this same little trickling stream, apparently undiminished in quantity, passing through the waste pipe at the end of the line. The pipe, contrary to the usual experience with stave pipe, was entirely tight from the beginning, which condition the author largely attributes to hard back-cinching, and the probable absorption of moisture from the damp back-filling. This particular piece of pipe was the only one on the line which permitted a determination of its tightness to be made independently of the steel pipe.

Cost.—The contract prices of the two chief items of this work were: Steel in bands, 4.8 cents per pound; lumber, feet B. M. in staves, measured before milling, $35 40 per M. The average spacing of the bands is $5\frac{9}{16}$ ins. The cost to the city, including all appurtenances, was 90.33 cents per foot, and 76 cents excluding such appurtenances. The whole amount of the contract was $36 100, and the total extra work cost $29 35.

The actual cost of the work the author does not feel at liberty to give by reason of the large personal interest of certain contractors being closely allied thereto. The distribution of the cost was as follows: Building and placing bands, 55%; back-cinching, 26%; repainting iron work, 3%; back-filling to depth of 6 ins. over pipe, 8.75%; placing specials, 3.5%; placing air valve, 0.75%; unclassified labor, 3 per cent.

The rate of wages paid for 10 hours was $1 75 for common labor and an average of $2 71 for foremen. It is presumable that the contract prices represent a profit of from $12\frac{1}{2}$ to 15 per cent.

The Steel Pipe.

Quality of Steel.—The specifications for the sheets used in the manufacture of the riveted steel pipe were the same as those for the bands of the stave pipe, with the exception that the test pieces were to be $\frac{3}{8}$ x 2 ins., and it was to be made by the open-hearth process.

Manufacture.—The sheets were 4 ft. in length. Alternate large and small courses were used, the small courses having the full nominal diameter of the pipe. The last of the eight courses constituting a length of pipe was made slightly conical, so that, being a small course

at the beginning, it was expanded to the size of a large course at the end. The addition of this course was a concession made to the contractor in order to constitute a saving in lead, the specifications requiring a large course at each end, and the addition of two courses making the sections too long for convenient handling or laying. In reality, little advantage was gained by the addition of this eighth course, owing to the difficulty of handling pipes of such length and making connection between them in the trench when using this conical course, and because of the more frequent necessity for cutting pipe in rounding curves. All straight seams were double riveted, and round seams single riveted, the seams being proportioned after Professor Kenneday's formulas for the use of iron rivets. The plates were punched from the sides coming together in the lap. The No. 12 steel was chipped and calked about the union of straight and round seams only, while the No. 10 sheets were beveled, and all seams calked with pneumatic calkers. Each length of pipe was required to pass through the testing machine, and to be tight under the following pressures: 14-in. pipe of No. 12 steel, 200 lbs. per square inch; 16-in. pipe of No. 12 steel, 175 lbs. per square inch; 16-in. pipe of No. 10 steel, 230 lbs. per square inch.

The author had some doubt as to the possibility of making riveted pipe of such light steel perfectly tight before dipping, under the pressures specified, and the manufacturers objected most strenuously to testing every piece.

In practice it was found that by putting every piece through the test, all spurting streams could be eliminated. Mere dropping was not regarded as serious in view of the coating still to be applied, and could not be wholly prevented. By insisting upon strict compliance in the matter of test, it is believed that very superior work was secured; such results as to tightness could scarcely have been secured, however, had not red lead been used in the lap on all joints. After test, the pipes were subjected to an asphalt bath applied under the customary conditions, and a most satisfactory coating was secured. By actual experiment it was found, after a very leaky pipe was coated, it could not be made to leak under any pressure short of bursting.

Joints.—The joints were made by the use of welded iron sleeves $\frac{3}{8}$ in. in thickness, 6 ins. in width, and having a lead space of about $\frac{3}{8}$ in. A reinforcing thimble of No. 8 steel, 8 ins. in width, was inserted half its width at the shop and riveted in one end of each pipe.

Oakum was only used to fill the crack at the junction of abutting pipe, none being used in the joint proper, the annular space being run entirely full of lead.

Cost.—Nothing of special interest attaches to the laying of this pipe, and by reason of inefficient management, coupled with much rainy weather, the cost to the contractor just about equaled the price received, which included laying and back-filling 6 ins. over the pipe. The price per foot paid by the city and the cost of the pipe to the contractor at the wharf were as follows:

Size.	Contract price.	Cost of pipe to contractor.
14-in.	No. 12.. $1 10	$0.85
16-in.	No. 12.. 1 18	.90
16-in.	No. 10 . 1 38	1.00

Pipe Line Fixtures.

Blow-Offs.—On the 18-in. pipe the blow-offs are all 6 ins., and on the smaller sizes, 4 ins. in size. They are provided with flanged gates and tangential connections, and are riveted to the steel pipes, while special castings are used for the stave pipe.

Overflow Waste.—A simple combination of stop gate with a relief overflow and stand-pipe is located on certain summits, by means of which the water can be partially or wholly turned off without in any way interrupting the continuity of the flow in that part of the line above the gate, thus rendering any overstraining of the pipe from undue pressure an impossibility. The height of the hydraulic gradient is also rendered adjustable within certain limits, whereby the stave pipe may be kept filled at all stages of flow. The stand-pipe also serves to admit or release air from the summit on which it is located, as may be required. An air valve connects with the pipe below the stop gates, for the purpose of admitting air when the water is drawn off while the gate is closed, as shown in Fig. 2.

Air Valves.—The air valves are the invention of Mr. Thomas W. Brooks, of San Francisco, and have been but recently brought into use. The author desires to testify to their satisfactory performance. They are made with two types of interchangeable valves ; one is a wooden ball with vulcanized rubber covering, and the other is a metallic valve having a concave lower surface. They remain open by their own weight until closed by the internal pressure; and are in-

stantly opened by any tendency to a vacuum within the pipe. They require practically no attention, and the water may be turned in or out of the pipe line with impunity, and without fear of interruption from air, either from within or without. An angle valve operated by hand provides for the release of any air accumulating while the line is in operation. The air valves have been arranged in groups of several of small size instead of one of large size, and are so proportioned that a sudden breaking of the pipe at the most dangerous points will not bring an atmospheric pressure on the pipe in excess of about 8 lbs. A suitable stop gate makes possible the removal of any of the valves without interruption to the flow.

Open stand-pipes are used in preference to air valves where practicable.

Suitable manholes of brick masonry, with wooden covers well fastened on, are built over all air valves, blow-offs and stop gates.

Pipe Line Experiments.

Capacity of the Pipe Line.—Just previous to the determination of the leakage in the reservoir, an 18-hour test was made to determine the delivering capacity of the pipe line. The measurement was made in the reservoir, it being empty at the beginning. Observations were taken of the height of the water surface once during the test, and again at its close. The results in the two cases showed a constant rate of inflow. The results computed from the total inflow were as follows:

Volume inflow in 18 hours....................	3 077 170	galls.
Rate " " 24 "	4 102 893	"
Add for loss by reservoir percolation..........	13 560	"
Total capacity of line in 24 hours.............	4 116 453	"

The loss by percolation is assumed to be constant for all depths, which assumption is, of course, not strictly correct, but the error is so small that its practical importance is nil. The rate of delivery promised the Commission was 4 000 000 galls., the amount made the basis of calculation was 4 050 000. The excess of delivery over the amount assumed in computation is about 1.6 per cent.

Determination of Leakage in Pipe Line.—To determine the amount of loss in the pipe line, the water was turned out of the settling basin until the indicated flow over the weir and into the pipe line was at the uniform rate in 24 hours of 326 690 galls., less a percentage of error in

the weir of 9 147 galls., making the net inflow at rate of 317 543 galls. The rate of flow at the lower end of the pipe line, after a lapse of sufficient time for the water to attain its uniform minimum flow, was determined by measuring it in the steel tank in the gate well. The following results were secured:

	To top of second course.	To end of experiment.
Depth of water................	9.19 ft.	17.11 ft.
Volume........................	447.92 cu. ft.	843.45 cu. ft.
Time of filling, in minutes......	19.18	36.10
Rate of inflow in 24 hours......	251 540 galls.	251 660 galls.
Add for average leakage through gates of tank..............	1 410 "	1 410 "
Net rate of pipe line discharge..	252 950 "	253 070 "

Net rate of pipe line discharge taken at 253 010 galls.

Apparent loss in line 317 543 — 253 010 = 64 533 galls.

In view of the fact that observations on a long section of the stave pipe when first filled showed it to be entirely tight, and that it has been necessary to correct quite a number of leaky lead joints on the steel pipe, even in places where the pipe was put under pressure and made entirely tight before covering, as was the case with almost all of it, it is believed that this loss must be accounted for by the existence of leaks of some magnitude in these lead joints, which the saturated condition of the ground at this season of the year has prevented being yet discovered. However the percentage of loss is believed at present to be smaller than is usually obtained in lines of similar length.

Determination of Frictional Loss in Pipe Line.—The existence of the open stand-pipes on the line afforded an excellent opportunity for the accurate determination of the loss of head between them. The following observations were made when the line was discharging its full capacity, 6 369 cu. ft. per second.

Station.	Actual Length.		Observed height in stand-pipe.	Elevation, computed.	Fall per 1 000 ft.
	Stave.	Steel.			
540			572.61	572.65	
	4187.66				1.9628
498.35			564.39	564.30	
	19130.56				1.9628
		16416.38			5.0023
144.25			444.72	444.50	

These are all the measurements which have been completed up to the present time, with the exception of an attempted determination of the fall in the hydraulic grade line between the settling basin and the stand-pipe at station 540. The result was a verification of that obtained between stations 540 and 498.35, but is omitted by reason of an uncertainty amounting to a few tenths of a foot in the entry head at the basin. It will be noticed that the fall used on the hydraulic grade line in construction was 2 ft. per 1 000 for the stave pipe, and 5 ft. per 1 000 on the riveted steel pipe. The almost exact coincidence between these figures and those actually assumed by the flow in the pipe is certainly remarkable, especially in a pipe line so frequently compounded. and where curvature is so freely used. The differences between actual and computed heights of water in the stand-pipes will be seen to vary from 0.04 to 0.22 ft., differences which are quite within the range of probable error in average level work. It will also be noticed that the greatest variation, 0.22 ft., occurs at station 144.25 after the water has passed from the previous stand-pipe through four different sections of 18-in. stave pipe and three sections of the 16-in. steel, in all aggregating about 7 miles. The actual frictional head per 1 000 ft. in the stave pipe is seen to be 1.9628 ft. In determining the loss of head in the steel sections, this value is assumed for the stave pipe between stations 498.35 and 144.25, making the frictional loss in the steel 5.0023 per 1 000 ft.

Substituting these results in the Chezy formula for the stave pipe, $c = \frac{v}{\sqrt{r\ s}} = \frac{3.605}{0.02713} = 132.88$, from which the value of the frictional coefficient n of the Kutter formula for c is deduced to be about 0.00985; and for the steel pipe:

$$c = \frac{4.584}{0.04083} = 112.3 \text{ from which } n \text{ is about } 0.0111.$$

Engineers will not fail to note the large advantage in small frictional loss possessed by the stave pipe over the steel, and to observe that the value of 0.010 for n, used by many engineers in dealing with stave pipe, is here found to be practically correct.

The author commends the result obtained from the steel to the consideration of those engineers who advocate tremendous allowances for friction in pipe of this character compared with those for cast-iron pipe; and as a whole, the results obtained, to the consideration of other engineers who have held that large shortages in delivering

capacity of gravity pipe lines may be accounted for by failure to avoid up and down hill travel, and in not accepting the alternative of heavy pressures and proportionally increased cost incident to more uniform grades on valley routes. That the present discharging capacity of the steel pipe will remain constant through a period of many years the author does not expect, while the almost perfect condition of the inside surface of the wrought-iron pipe taken up from the original pipe line, after carrying Bear Creek water for twelve years indicates that there will probably be no very serious falling off.

The Reservoir.

The reservoir has a capacity to the level of the overflow pipe of 6 250 000 galls., and has a depth of 17.4 ft. to the flow line, and 20 ft. to the top of the parapet wall. The general shape is that of the hill on which it was built. The embankment is quite uniformly about 5 ft. in height on the inner slope, except at one point where it is 15 ft. in height. The remainder is in excavation. The top of the bank is about 23 ft. in width; and varies from 0 to 35 ft. in height above the toe of the outer slope. Both inner and outer slopes were intended to be 2 to 1, but the disposal of a considerable quantity of surplus material left the outer slope in places somewhat steeper than this.

Excavation.—The materials in which the excavation was made consisted of much black indurated clay, and a fine grained sand mixed with clay, which in places approached soft sandstone in character. All material was plowed, and when broken was in excellent condition for handling with wheel scrapers. When excavated, it possessed just the right degree of moisture to solidify to the best advantage without the addition of water. All surface soil containing roots or other vegetable matter was first removed, and care taken to secure a proper bond between the natural ground and the made earth. The banks were carried up in layers 6 ins. in thickness, and were thoroughly rolled with a smooth roller weighing 3 000 lbs. to the lineal foot. On the inner slope the bank was made 1 ft. wider than the finished work, and afterward dressed to the proper plane. By the use of slope boards and lines, the whole inner surface was dressed very truly to the desired form without any after-filling being necessary. The price paid for the excavation, 15 cents per cubic yard, included the clearing of the site, previously covered with burned timber, and the construction of the embankments.

The cost to the contractor, 16.9 cents, was needlessly large, as the haul was made unnecessarily long during much of the work, and a scarcity of ready cash made it difficult for the contractor to get rid of worthless men. The total amount of excavation was 49 540 cu. yds.

The Lining.

On the bottom, the reservoir is lined with 6 ins. of concrete laid with expansion joints, $\frac{3}{8}$ in. of cement mortar, one coat of liquid asphalt, and one asphalt coat of harder consistency. The slope lining consists of 6 ins. of concrete laid with expansion joints, one coat of asphalt, one layer of brick laid flat after dipping in hot asphalt, and a final finishing coat of asphalt.

The parapet wall surrounding the reservoir is 2 x 4 ft. in section and built of basalt, with rough rubble backing and squared face stones. It is surmounted with a 9-in. course of coping stone, on which is erected an iron picket fence 5 ft. in height.

General Design.—In the design of this reservoir the author endeavored to secure a lining which would at a reasonable cost fulfil the following somewhat ideal conditions: It should not readily break down over slight local settlements; if it did break down the impervious surface should bend down and not break. It should not crack from expansion and contraction, but if it did crack, no leakage should occur. It should be permanent, and, finally, it should be practically water-tight. The lining adopted is believed to meet all of these conditions. The author has tried reservoir linings made by laying brick dry on a layer of coarse underdrained gravel, and then coating it with asphalt; of asphalt mastic covered with asphalt, of brick laid in cement mortar and coated with asphalt, and of asphalt directly on concrete. All have proved sufficient for the purpose, and some of them especially useful as expedients where large results were required from small expenditures, but he feels that the lining adopted for the present work more nearly meets all the requirements of an ideal reservoir lining than any other with which he is familiar. The cost per square foot, without profit, was as follows:

Slope.		Bottom.	
6 ins. concrete	$0.1187	6 ins. concrete	$0.10311
First coat asphalt 0.649	0.01005	Cement mortar finish	.01126
Brick in asphalt	0 08886	First coat asphalt 0.537	.00768
Second coat asphalt 0.851	0.01307	Second coat asphalt 0.573	.00821
Chinking crevices	0.00300		
Ironing	0.00356	Total	$0.13026
Total	$0.23724		

Average cost for the entire reservoir, $0.17965 per square foot.

Concrete.—The concrete is composed of crushed basalt rock, $2\frac{1}{2}$ ins. in maximum size, quarried and crushed near the work; Columbia River gravel, a very clean fine black gravel containing much coarse sand; fine sharp sand, and imported Portland cement. One cubic yard of concrete contained 0.9 cu. yd. of crushed rock, 0.5 cu. yd. of gravel, 0.1 cu. yd. of sand, and one barrel of cement.

All mixing was done by hand on movable platforms in $\frac{1}{2}$-cu. yd. batches. Three gangs were usually employed, each having six mixers, who also placed the concrete for the two men engaged in finishing and tamping. The coarser rock were raked forward and down, leaving the finer material at the surface, and a long straight edge was used in securing a uniform surface. All three gangs were served by nine wheelbarrows, five handling rock; three sand and gravel, and one, cement. A helper at the cement, one man tending water, one sprinkling concrete already laid, and the water boy, made up the concrete force. The sand, gravel and cement being first thoroughly mixed, water was then added, mixed and spread, and the wet stone added. It was then turned three times on the mixing platforms, and once more when deposited. On the slopes a rough finishing coat was applied as soon as the batch was in place, by the application with a shovel of a little mortar taken from the next mix. A very good surface, smooth and free from stones was thus secured for the laying of the brick, while the comparative roughness of the surface gave the asphalt coat a very perfect adhesion.

On the bottom, the $\frac{3}{8}$-in. finishing coat of cement mortar was applied as fast as the concrete was placed by two finishers using smoothing trowels, who were served by four men mixing and carrying. The mortar was mixed in the proportions of two to one of fine sand and cement. In all concrete work no more water was used than was necessary to mix properly, only a very little showing on the surface when tamped. When the ground was hot and dry, water was sprinkled on it in advance of the concreting. On the slopes the concrete was placed in sheets 10 ft. wide, extending up and down the slopes. On the bottom it was placed in squares measuring 20 ft. on a side. These boundaries were maintained when placing concrete by means of a 2 x 6-in. plank, the straight edge being used between these in securing a uniform surface. When connection was made between sheets the 2 x 6-in. plank was replaced with a piece of beveled $\frac{1}{2}$-in. ordinary weather boarding,

4 ins. in width. After the concrete had thoroughly set, about two weeks after placing, these strips were removed, and in making application of the first coat of asphalt, the grooves were run full. There was no difficulty in removing the beveled strips, but some strips with vertical sides and an occasionally inverted beveled one proved exceedingly troublesome. Plate I, Fig. 2, illustrates the appearance of the reservoir during the progress of the concrete work.

Expansion Joints.—These expansion joints have fulfilled every expectation. Not a crack has appeared anywhere in the concrete. Their operation was very noticeable during warm weather, especially in the bottom. In the cool early morning they were much depressed, while in the heat of mid-day they presented the appearance of ridges discernible clear across the reservoir, the amplitude of the motion being in many cases fully $\frac{3}{8}$ in. Observations made by the author on a large concrete-lined reservoir, recently built without any provision for expansion and contraction, in which cracks had formed up and down the slope for a distance of several hundred feet at remarkably uniform intervals of about 25 ft. leads him to think about 20 ft. a suitable maximum spacing for expansion joints in concrete laid in this climate. By reason of its superior elasticity the author considers the use of pure asphalt of medium hardness much superior to any mixture of asphalt and sand for this purpose, with suitable provision for holding it on the slope, and doubts the efficiency of a mastic unless made very rich in asphalt.

Cost of Concrete.—There were 603.3 cu. yds. of concrete used on the slopes, which cost the contractor \$1.072 a yard for labor and \$1.939 for materials, except cement, which was furnished by the city, and cost \$2.822 per yard of concrete. The amount of concrete on the bottom of the reservoir was 678.2 cu. yds., and cost the contractor \$0.674 per cubic yard for labor and \$1.923 for material, except cement; this was furnished by the city and cost \$2.641 per yard of concrete. The contract price was \$3 50 per yard, exclusive of cement. The total cost of the cement coating was \$1.126 per 100 sq. ft. That the work was well managed is apparent from the fact that 1.84 cu. yds. of concrete was mixed and placed each day for each man employed. On the bottom alone, this amount was increased to 2.35 cu. yds. For work of this character the author considers this a creditable showing, for he has known instances where the labor account amounted to four times as much on

work of a similar character but larger proportions. For most of this work Italians were employed who were experienced in concrete work. The crushed rock was secured from a quarry located about 800 ft. from the reservoir, at about the same level, and delivered on the work at a cost of 95.28 cents per cubic yard. The sand and gravel were dredged from the Columbia River and delivered by sub-contract at the wharf at a cost of 86.59 cents per cubic yard.

Cement.—The city purchased by contract all the cement used on every part of the work at a cost of $2 45 per barrel delivered at the wharf, as needed on the work. In all about 3 100 barrels were used, of which 1 558 went into the reservoir lining. Most of this was of a superior quality. Every sixth barrel was tested for tensile strength, with frequent tests for blowing, and time of setting. Only seven barrels were rejected, these having deteriorated by exposure to weather.

The Asphalt Work.—The asphalt used in the work was all of the Alcatraz brand. Two grades were employed; the L (liquid), and XXX (paving cement). The first is a natural liquid asphalt, and the second is the product of refining the natural rock asphalt with about 20% of the liquid as a flux. Both grades are now placed upon the market in barrels holding about 400 lbs. As a rule no asphalt was applied to the concrete until the latter had been in place fully two weeks, and was well dried on the surface, though some slight variation from this rule was unavoidable by reason of the work being overtaken by the fall rains before completion. On the bottom was first applied a coat of the L grade, which was followed by a coat of the XXX paving cement. On the slopes none of the L grade was used by reason of the tendency to creep, which a soft underlying coat always produces, and so often mars the appearance of work on reservoir slopes. The author, after a considerable experience in using asphalt in different ways as a reservoir lining, is disposed to believe that any advantages possessed by a soft coat over a harder one, as a first application, is more fancied than real. At the proper temperature, the harder grade runs just as readily, and enters all crevices just as surely when applied, and if the masonry be entirely dry and clean, and preferably a little rough, it adheres more tenaciously than the liquid. The only superiority possessed by the latter as a first coat is that if it must be applied on a damp surface, it will adhere where the other will not.

All dust was carefully swept from the concrete, as it effectually prevents any bond, and the asphalt was applied with mops made from twine used in the local salmon fisheries. The mops were served from large sheet-iron buckets, which were kept filled by attendants, who carried asphalt from two large kettles holding about 3 000 lbs. each, in which it was melted and kept at the proper temperature. The bricks used on the slopes were about half vitrified and half common, the contractors being disappointed at the last moment in the delivery of the requisite number of the former. As laid they were submerged in a bucket of hot asphalt, and placed in position on the slope by means of iron tongs. Sufficient asphalt always streamed from the brick to fill entirely all irregularities beneath it. A push joint was made, much as when laying brick in cement mortar, but much more expeditiously. For the sake of close joints and consequent economy in the use of the asphalt, it proved very important to keep the temperature high enough for the asphalt to run like water, which is the manner in which it should always be used to secure the best results. Common laborers could, with a little practice, when well supplied with materials, readily lay an average of 2 300 bricks in 10 hours. The finished coat of asphalt followed as speedily after the brick laying as possible, in order to avoid delay from rain, as the water standing in unfilled joints dried out very slowly. In applying this coat an effort was made to fill all joints, and where this could not be done with hot asphalt on a slope, a rich mastic of sand and asphalt was used. This much improved the appearance of the work, as the brick were quite rough and somewhat irregular in shape. The connecting joint between the top of the lining and the base of the parapet wall was also run full of asphalt. A final smoothing was given the finished surface by going over the slopes with hot irons. Although the general appearance of the surface was by this means much improved, the author is rather loath to trust hot iron in the hands of common laborers on an asphalt surface. Unless most carefully watched, overheating and consequent serious injury are almost certain to occur. When this lining had been exposed to the rays of the sun for a considerable time, there was a very noticeable sliding of the brick on the slope, and a consequent closing up of the joints, crowding out the asphalt where they were thick by reason of the asphalt having been used too cold on days that were too windy to permit it being

maintained at a proper temperature. As a consequence, openings were produced between the brick lining and the wall at the top of the slope, which were filled with mastic. The footing course of brick was prevented from sliding by being set into the concrete of the bottom lining. After a few weeks all motion ceased entirely.

In order to secure the best results possible, all asphalt work should be performed during the dry summer months. Such was the plan for the Astoria work, but the delay in beginning carried the date of completion over into the rainy season. By careful management in keeping the work in proper shape for speedy drying, no especial difficulty was experienced except with the brick. Although they were housed at the reservoir, and piled and fired when rained on during transportation, sufficient moisture was apparently absorbed from the air to produce by evaporation small bubbles or blisters on the surface when dipped in the hot asphalt. No similar difficulty was experienced with brick laid during the dry weather. This defect is one of appearance rather than reality, and is but temporary, as the steam soon condenses and the bubble collapses. Although the adhesion between the brick and the asphalt is sometimes destroyed over the limited area covered by these bubbles, the effect is simply to permit these brick to become more quickly saturated than would otherwise be the case. It must not be assumed, as has been so often stated, that asphalt renders anything wholly impervious to water, or is of itself impervious. On the contrary it may be readily demonstrated by a simple experiment that a brick thoroughly coated and recoated will in time absorb as much water as an uncoated one. The advantage of the asphalt lies in its retarding effect on the passage of water ; it does not exclude it.

Cost of Asphalt Work.—Tables Nos. 1 to 7, inclusive, showing the amount, cost and distribution of both labor and materials employed in the asphalt work, are prepared in a way that is believed to make the probable cost of other similar work easily determinable. In view of the interest which the use of this material as a reservoir lining is very properly creating among engineers, especially in the East, this presentation may not be untimely.

Iron Fence.—On top of the coping which surmounts the parapet wall is erected an iron picket fence 5 ft. in height, having pickets ½ in. square, spaced 4 ins. between centers. The rails are small channel irons 2 ins. in width. No attempt is made at ornamentation. The

panels are 8 ft. in length, and at the end of each a post picket extends 4 ins. into the stone. Each post is braced from the face of the wall, the brace also having a tie fastening into the top of the wall, making three drilled holes necessary for each panel. The panels are supported half way between the posts. Both supports and braces are made adjustable by means of movable clips and set screws, rendering possible the securing of perfect line and grade. All joints were made with lead and calked. This fence was designed and made by the Van Dorn Iron Works, of Cleveland, and was erected by day labor under the supervision of one of the assistant engineers, without a foreman, at a cost of $985 40 for a total length of 917.2 lin. ft.

Aerating Fountain.—At the center of the reservoir is a 12-in. entry pipe leading from a connection with the gravity conduit in the power house, and passing up through a concrete pedestal. It terminates a little above the surface of the water in a brass fountain head, having about 300 holes, ranging in size from $\frac{1}{16}$ to $\frac{9}{16}$ in. in diameter, arranged in concentric rings with the larger at the center, and gradually diverging from the perpendicular to an extreme angle of 35° on the outer circle. Through this the water may be turned from the pipe line, when not used for the development of power, and the reserve head may be used in the formation of an aerating fountain. Its construction was a natural consequence of having a reserve head for power development. It proved a very ornamental feature, and is expected to be useful in securing aeration and free circulation in the water, which is necessarily heavily charged with vegetable matter, and, when allowed to stand in a reservoir without circulation for a considerable time in the summer, has developed very offensive qualities.

At the foot of the fountain pedestal, in the 12-in. supply pipe, is a stop gate, and a double nozzle fire-hose connection for the purpose of securing streams for cleaning out the reservoir.

Total Cost of Reservoir.—The total cost of the reservoir, exclusive of iron fixtures, which are included in the cost of the gate and power house, is summarized in Table No. 8.

Reservoir Leakage.—When first filled, careful observations were made to determine the rate of leakage from the reservoir. The depth of water was about 14 ft.; the time elapsing between the observations was 68 hours. As the air was in a state of saturation all the time there was no occasion to make deductions for evaporation. The rainfall

record was taken from the reports of the local signal service. The results were as follows :

Total rainfall	7 384 cu. ft.
Total quantity retained	2 253 "
Total leakage	5 136 "
Total leakage in gallons in 24 hours	13 553 galls.

Total leakage in gallons in 24 hours per 1 000 sq. ft. of lining submerged, 232.1 galls.

Assuming the absence of evaporation, and that the rate of leakage is uniform for all depths, it would require a term of years for the reservoir to empty itself in this way, since the average rainfall is 75 ins. For a new reservoir filled for the first time, and with consequently no opportunity for sedimentation, the results are gratifying. A second experiment of similar nature, made a few days later, gave results identical with the preceding.

The Power and Gate House.

There is a surplus fall in the mile of 14-in. steel pipe at the end of the conduit, which is to be used for the development of power by Pelton wheels for the operation of an electric plant for the illumination of the streets and public buildings, and for pumping a water supply to the districts not capable of being supplied directly by gravity.

The Building.—The gate house for controlling the water at the reservoir and the power house for the light and pumping plant have been united in one building of basalt masonry, with cut face stones laid random, and rubble backing. It has a copper roof, is sealed throughout the lower story with red wood, finished in the natural grain, and has three living rooms finished off upstairs for the residence of the keeper. The end enclosing the gate well is semi-circular in form. The building as a whole presents a pleasing effect, which should be credited to Mr. J. E. Ferguson, the architect.

Arrangement of Power-House Fittings.—The arrangement of the power-house appliances may be readily understood from the plan (see Fig 3). The water passes directly through the building to the fountain in the reservoir. When the power is utilized for work, the fountain is cut out and the water discharged through the nozzles of either of the Pelton wheels. The tail water is conducted the length of the building

in a concrete channel under the floor and discharged into a 14-in. pipe leading into the gate well. It will also be noticed that provision is made for connecting the suction of the pump to be installed later directly to the pipe under the same pressure as the nozzle operating

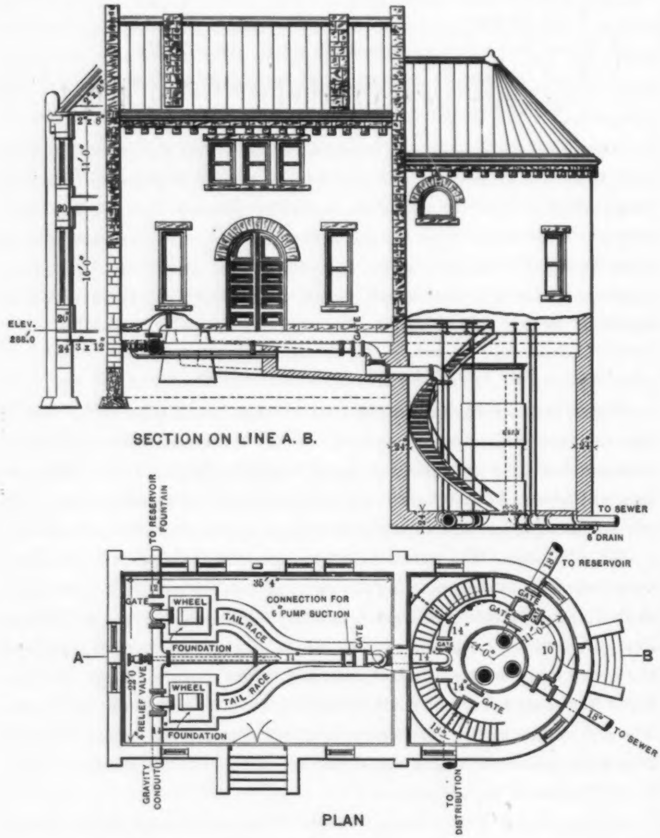

FIG. 3.

the wheel which is to drive the pump, thus diminishing by that amount the work necessary to be done in elevating the desired amount of water, which will never exceed 200 000 galls. in 24 hours. When the flow at the power-house is entirely stopped for any reason, and the

water allowed to waste through the overflow at the head of the 14-in. line, a 4-in. relief valve discharging into the tail race affords a safeguard against any ram likely to be produced in the closing of the gates.

The Gate Well.—Fig. 3 gives a very good idea of the general arrangement of the gate well. It is 22 ft. in clear diameter, and is lined with 2 ft. of concrete. In the center of the well is a steel tank 8 ft. in diameter and 21 ft. in height, built of ¼-in. plate. This tank has pipe connections with the reservoir, the distribution and the sewer, and indirectly with the tail race from the Pelton wheels, through which the flow of the pipe line can also be turned independently of the wheels. All surplus water passes through this tank to the waste through the open stand-pipe, the top of which stands at low-water mark for a full reservoir.

From the arrangement of connections and gates, it will be seen that the reservoir or the tank may be temporarily cut out without affecting the supply to the distribution. The overflow is always operative whether the reservoir is in use or not, and the fresh water from the pipe line will always first meet the demand from the distribution, until the supply is exceeded, when the reservoir is drawn upon for the deficiency. A cylindrical brass screen, not shown in the drawing, is inverted over the distribution supply pipe in the tank. This screen can be cleaned at any time by reversing the flow through it. Two feet of concrete is placed in the bottom of the well, enclosing the fittings, and constituting the bottom of the tank. An independent drain pipe provides for the discharge of all seepage water from the well. A spiral iron stairway, supported on the wall by brackets, affords a convenient means of entering the well, while the tank may be entered from above by a stationary iron ladder down the inside. All gates are operated from above by means of hand wheels supported on vertical gas-pipe shafting.

The total cost to the city of the buildings and fittings was $10 177 25.

The Tunnel.

The tunnel through which the distributing system connects with the new reservoir extends directly north from the gate house through the intervening ridge, and is about 1 200 ft. in length. Of this distance, the first 300 ft. from the gate house averages about 20 ft. in depth below the surface, and was tunneled by the contractor in prefer-

ence to digging open trench. The remaining 900 ft., except for a portion which is through solid rock, is lined with concrete and terminates in a manhole at each end.

Excavation.—The 300 ft. at the south end, which was afterward refilled, was driven through a rather soft argillaceous yellow and blue shale. The remainder, with the exception of about 250 ft. of solid rock near the center of the tunnel, was through an exceedingly hard, compact black shale, which required powder for its removal and rapidly disintegrated when exposed to the air. Timbering was necessary everywhere except in the solid rock section, and consisted of 6 x 6-in. posts and caps, 2 x 12-in. sills and 2-in. lagging. The posts were usually spaced 2 ft. between centers, and were not infrequently crushed in by the swelling of the material, in places where there was apparently no tendency to cave. In places where water penetrated in considerable quantities, the disintegration was so rapid that the tunneling was done with great difficulty, and though timbering was kept close up, several bad caves occurred.

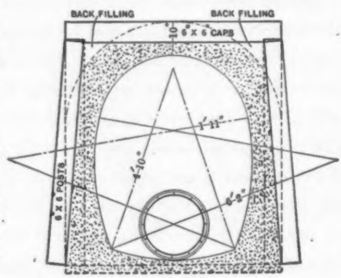

Fig. 4.

The rock was very hard basalt, and was worked entirely by hand. Air was supplied by an exhaust fan operated by an electric motor taking current from the wire of an electric street railway. Driving was usually conducted from both ends. The section driven throughout was 5 ft. 5 ins. in width by 6 ft. in height.

Lining.—It was the original intention to put in a lining of brick with vertical sides and arched top, but the material penetrated proved disappointingly unstable, and the completion of the tunnel driving was so long delayed by reason of the quantity and hardness of the rock encountered, and by the failure of the original contractors, that the work of lining was necessarily performed long after the heavy fall and winter rain had rendered the ground very treacherous, so that it was found inexpedient to remove all the timbers in very many places. It was accordingly determined to use a strong concrete section for the lining, and leave in much of the timbering. Fig. 4 shows the form of section adopted, and the disposition made of the posts in order to

secure a sufficient thickness of concrete between them and the forms without removing them, the earth being dug away from behind them at the foot of each, and the post pushed back out of the way. The forms were built in 4-ft. sections for the sides, and 2-ft. lengths for the top, and were held in position by 1 x 4-in. bracing on the inside. The concrete was well rammed into all crevices, except at the upper corners, and where considerable caves existed, which were filled back of the concrete with the excavated material. The proportions used in the concrete were the same as those used in the reservoir work, with the exception that the screenings were not removed from the rock. The work of lining in the north end was much delayed by reason of the large amount of digging necessary in securing proper line and grade, this matter having been very carelessly looked after by the men doing the driving. The work in its completed condition is in a very satisfactory shape, which result has been secured only by most untiring supervision.

Cost.—The work passed through many vicissitudes, being at different times under the management of three different contractors and subcontractors. The excavation in the softer materials was not well handled. The rock excavation and concrete work were well managed, and the cost very carefully kept. The cost of the tunnel to the contractors and to the city is given in Table No. 9.

Tunnel Pipe.—The main supply pipe from the new reservoir to a connection with the high-service distribution is 18 ins. in diameter. That in the part of the tunnel which was refilled, and that which lies without the tunnel to the north, is of cast iron $\frac{11}{16}$ in. thick, while the portion lying within the permanent tunnel is wood-stave pipe. Little room was left in the concreted section for the building of pipe, but it was accomplished without difficulty, the gang making an average of 132 ft. a day.

Distributing System.

The distributing system as at present arranged is divided into a low and a high service, the low being supplied from the small reservoir of 500 000 galls. capacity built by the Columbia Water Company at a flow-line elevation of 167 ft.; and the high service being supplied from the new reservoir previously described.

The New Service.—The street mains in the low service range in size from 6 ins. to 14 ins., and in their arrangement and size are designed to

secure a delivery in case of fire in any of the business portions of the city of 2 000 galls. per minute, in addition to the ordinary domestic consumption, at an effective pressure of 80 lbs. at the hydrant nozzles. Part of the pipe is cast iron, and part steel kalamein pipe.

Astoria has no sea wall, and many of the streets in the business part of the town are supported on pile trestles about 18 ft. high. On these streets the kalamein pipe is used by reason of its lightness and greater adaptability to withstanding vibration than the cast iron. Wherever supporting ground exists, cast-iron pipe is used. The kalamein pipe is supported below the street surface on timbers dapped into and bolted to the piles, and is boxed with 2-in. lumber, the box for the 12-in. pipe being made without a cover. The gauges are the customary standards used by the manufacturers of this class of pipe : 6-in., No. $11\frac{1}{2}$; 8-in., No. $10\frac{1}{2}$; 10-in., No. 10, and 12-in., No. 8.

The hydrants on these streets are connected with the street mains by a section of similar pipe, having a cast flange attached to each end, the pipe being expanded like boiler tubes with a hammer to fit the slightly rounded inner edge of the flange, thus removing any possibility of the hydrant being pushed off by the pressure, while a lead joint provided at the outer end of the flange makes the connection water tight. The cast-iron pipe is all of the hub and spigot type of the following thicknesses :

Diameter, inches	14	12	10	8	6
Thickness, "	$\frac{3}{4}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{9}{16}$	$\frac{1}{2}$

At the foundry frequent tests of the quality of the metal were made by the inspector with the following results :

		Pounds per square inch.
Test piece, 1 in. square.....	Least strength......	18 500
	Greatest "	29 500
	Average "	22 000
Test piece, $\frac{13}{16}$ in. round.....	Least "	19 000
	Greatest "	32 000
	Average "	26 500

Test bars 1 × 2 ins., 24 ins. between supports, load applied at center.

	Breaking load.	Deflection.
Least....................	2 000 lbs.	$\frac{1}{4}$ in.
Greatest................	2 700 "	$\frac{3}{8}$ "
Average.................	2 230 "	$\frac{11}{32}$ "

All pipes were tested to 300 lbs. pressure, and well hammered during the process. Asphaltum was used for coating. The special castings were all made after special drawings, thus dispensing with the unnecessary length and weight of most foundry patterns. Pipes were laid with 3 ft. of earth cover, and with 2 ins. of lead in the joints.

The High Service.—The old pipe taken up from the gravity line of the old works and from the old distribution is largely used for the high service. The former is lap-welded wrought iron supplied with the Converse lock joint, and the latter is principally cast iron of the ordinary hub and spigot type, of a thickness suitable for about 150 ft. head. The pipe for this service ranges from 6 to 10 ins. in size. Be-

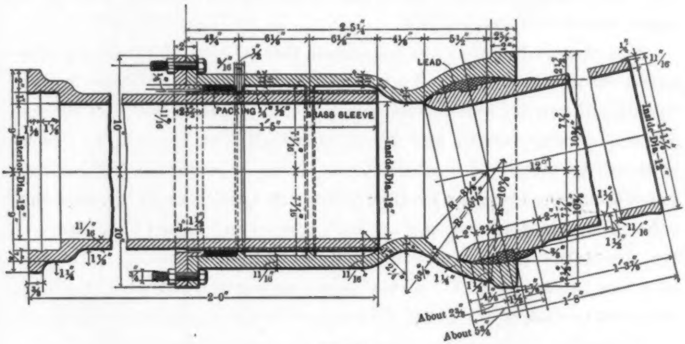

FIG. 5.

fore laying it was all cleaned with steel wire brushes, tested under hydrostatic pressure, and recoated with asphalt.

Hydrants and Gates.—The gates are so distributed as to permit a line to be cut out without disturbing the rest. On the trestled streets, beside being placed at intersections, they are put in every two blocks as a safeguard against loss of pressure by the falling of street mains in event of an extended conflagration. All were tested to 300 lbs. pressure, and are provided with adjustable cast-iron gate boxes. The hydrants have 6-in. connections with street mains, and 5-in. clear valve openings, and are provided with two 2½-in. hoze nozzles, and a 5-in. steamer nozzle. They also were tested to 300 lbs. pressure.

Flexible Slip Joints.—In some sections of the town the ground is of a very sliding character, the street improvements at some of these points being gradually pushed out of line as much as 2 ft. in a year. In the laying of the street mains, these sections have usually been avoided. It was necessary, however, that about 1 000 ft. of ground of this character be crossed with a 12-in. pipe. To meet the difficulty, a combination slip and flexible joint was devised, shown in Fig. 5. These were distributed at intervals of about 200 ft., and the pipe enclosed for a distance of 50 ft. on each side with a covered wooden box, considerably larger than the pipe, in order to give room for motion, without the pipe having to take the weight and friction of the earth. The ball and socket joint is patterned after the New York City standard, and was so nicely turned that when stood on end, the lead space held water wholly without leakage.

Fire Gates.—Mention has been made that in case of fire, the pressure is secured through the high service from the new reservoir, by the opening of two fire gates which connect the low with the high service at two extreme points, and by automatically cutting out the lower reservoir by means of a check valve in its supply pipe. These fire gates are of the ordinary Ludlow piston lift type, one 14 ins. and the other 10 ins. in diameter, and are both opened and closed from the central fire station by opening and closing an ordinary stop-cock at the end of a line of ordinary $\frac{3}{4}$-in. service pipe leading to a patented governor attached to each of the gates. This governor was especially designed by the author to meet the conditions here existing, where the lower reservoir elevation was sufficient for ordinary domestic consumption, but insufficient for a really good fire protection directly from the hydrants, while the upper reservoir was at a suitable elevation for a first-class fire pressure, 113 lbs., but objectionably high for domestic use. The device is suited for operating from a distance any piston lift gate working in a pipe under pressure. It would seem to be an economical and efficient arrangement for the speedy closing of gates in large principal supply mains in case of disastrous breaks such as not infrequently occur. It has worked in the present instance without any failure from the beginning, and has proved very certain in action. Its operation is simple, and is readily followed by the aid of Fig. 6. *A* is connected with the pressure pipe or main in which the gate is placed which is to be operated by the governor, *B* with the lower end of

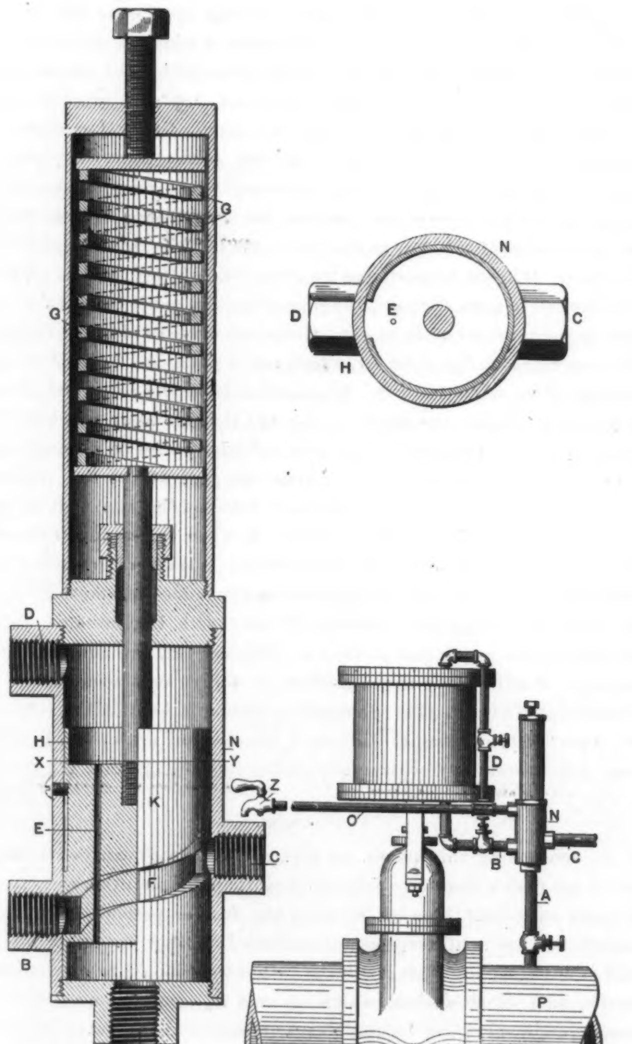

FIG. 6.

the gate cylinder, *C* with the waste, *D* with the upper end of the cylinder, with a **T** connection, in one branch of which is connected the small pipe *O* leading to the fire station from which the gate is to be operated. At the end of this pipe is placed a stop-cock or other convenient means of opening and closing this pipe. Under normal conditions the pipe is closed, the water has free access from the pressure pipe *P* through *A*, *E* and *D* to the upper end of the gate cylinder, thus acting on the gate piston and keeping the gate closed. There being an equilibrium of pressure in the two ends of the governor cylinder, the spring *G* keeps the piston at the lower end of the cylinder. When it is desired to open the gate, the pipe at the fire station is opened, releasing the pressure at *D*, causing the governor piston to be thrown to the upper end of the cylinder, which act closes *D* and opens *B* to the passage of the water from *A*. The water acts on the lower end of the gate piston, causing the piston to rise and the gate to open, while the water from the upper end of the gate cylinder passes off through the pipe *O* at the fire station. By closing the pipe at the fire station, equilibrium is again gradually restored between the two ends of the governor cylinder through the opening *E*, when the spring *G* throws the piston to the lower end of the cylinder, releasing the water from the lower end of the gate cylinder through the pipes and movable port *B*, *C* and *F*, leaving the gate free to close with the pressure again restored to the upper end of its lift cylinder. By reversing the connections, it will be seen that a gate can be always kept open instead of closed while the cock at the controlling station is kept closed. As set up, a pair of 1½-in. flanges holding a wire screen are inserted in the pipe *A* to prevent any obstruction getting into the opening *E*.

Conclusion.

In concluding this paper, no instructive lessons can be recorded which are drawn from any failures unanticipated or otherwise, since in every particular the work has been free from experiences of such a nature, and has in all respects accomplished all that was either promised or anticipated. This result the author feels should be very largely attributed to that wisdom which secured as commissioners men of sound judgment, good business sagacity and sterling integrity, and which removed them as a body beyond the pale of political influence. Not the least of their acts of wisdom which contributed to the success

of the work was their recognition of the responsibility which rested upon the chief engineer, by leaving him entirely untrammeled in the selection of his assistants and the managing of his department. This leads the author to the pleasant task of here recording his sincere gratitude to the engineers associated with him, for their manifestation of high ability, untiring energy, and loyal co-operation in securing the largest measure of success possible. Among those to whom he is much indebted are James D. Schuyler, M. Am. Soc. C. E., who reported on the plans for the work in the fall of 1894, and to whom he is under obligations for many excellent suggestions; R. C. Gemmell, M. Am. Soc. C. E., who, as a partner, was associated with the author in the early preliminary work on plans and specifications; A. S. Riffle, M. Am. Soc. C. E., mechanical assistant on construction, and assistant engineer in charge of reservoir, gate and power house, and tunnel; J. F. Case, assistant engineer in charge of pipe line and head works; George A. Shields, shop and foundry inspector and assistant engineer in charge of the distributing system, and Lars Bergsvik, in charge of construction surveys.

TABLE No. 1.—Cost of Asphalt Coat on Slope Concrete—29 637 Sq. Ft.

Labor.	Total.		Total cost.	Total cost per square foot.
	Hours.	Rate.		
Buildings, sheds, etc.	....	....	$5.00	$0.000168
Spreading	91	At $0.20	18.20	0.000614
Boiling	91.5	" 0.15	13.72	0.000462
Attendance	73.5	" 0.15	11.025	0.000372
Sweeping	49.5	" 0.15	7.425	0.000251
	305.5			
Material.	Quantities.			
Asphalt	19 243 lbs.	" 0.01225	235.729	0.007950
Haul	9.6 tons.	" 0.4700	4.500	0.000152
Fuel	1.0 cord.	" 2.50	2.500	0.000084
Totals	....	....	$298.102	$0.010053
Contract price	....	....	$657.94	$0.022222

TABLE No. 2.—Cost of First Coat of Asphalt on Concrete Bottom—34 454 Sq. Ft.

Labor.	Total. Hours.	Rate.	Total cost.	Total cost per square foot.
Building sheds	25	At $0.20	$5 00	$0.000146
Spreading	38	" 0.20	7 60	0.000220
Boiling	37	" 0.15	5 55	0.000161
Attendance	43	" 0.15	6 45	0.000186
Sweeping	44	" 0.15	6 60	0.000191
	162			
Material.	**Quantities.**			
Asphalt	18 490 lbs.	" 0.01225	226 50	0.006578
Haul	9.25 tons.	" 0.470	4 35	0.000126
Fuel	1.0 cord.	" 2.50	2 50	0.000073
Total cost	....	....	$264 55	$0.007681
Contractor's price	....	....	$765 68	$0.0222222

TABLE No. 3.—Cost of Second Coat of Asphalt on Bottom—34 154 Sq. Ft.

Labor.	Total. Hours.	Rate.	Total cost.	Total cost per square foot.
Building sheds	....	....	$5 00	$0.000146
Spreading	35	At $0.15	5 25	0.000153
Boiling	30	" 0.15	4 50	0.000132
Attendance	52.5	" 0.15	7 88	0.000230
Sweeping	44.5	" 0.15	6 68	0.000195
Foreman	17.5	" 0.25	4 38	0.000128
Material.	**Quantities.**			
Asphalt	19 591 lbs.	" 0.01225	239 99	0.007019
Haul	9.8 tons.	" 0.470	4 61	0.000134
Fuel	1.0 cord.	" 2.50	2 50	0.000073
Total cost	....	....	$280 79	$0.008210
Contractor's price	....	....	$758 90	$0.022222

TABLE No. 4.—COST OF LAYING ON SLOPE BRICK DIPPED IN ASPHALT —132 000 BRICK, 29 637 SQ. FT.

LABOR.	TOTAL.		Total cost.	Total cost per "M."
	Hours.	Rate.		
Unloading brick from barge...... At wharf..........	290 22	At $0.15 " 0.25	$49 00	$0.37122
Haul and storage at the Reservoir........	160 140 129.5	" 0.35 " 0.55 " 0.15	152 43	1.15473
Laying..........	561	" 0.15	84 15	0.63750
Attendance..........	1 341	" 0.15	201 15	1.52337
Briding asphalt..........	220	" 0.15	33 00	0.24999
Foremen..........	96	" 0.25	24 00	0.18180
	2 959.5			
MATERIAL.	QUANTITIES.			
Brick at..........	....	" 7.00	924 00	7.00000
Asphalt..........	93 372 lbs.	" 0.1225	1 143 81	8.66516
" haul..........	46.7 tons.	" 0.47	21 95	0.16628
Total cost..........	....	....	$2 633 49	$19.95055
Contract price..........	57 000 75 000	....	$2 500 50	$21 50 17 00

TABLE No. 5.—COST OF ASPHALT FINISHING COAT ON BRICK SLOPE LINING, 29 637 SQ. FT.

LABOR.	TOTAL.		Total cost.	Total cost per square foot.
	Hours.	Rate.		
Building sheds, etc..........	....	....	$5 00	$0.000168
Spreading..........	95.75	At $0.15	14 36	0.000485
Boiling..........	73.25	" 0.15	10 99	0.000371
Attendance..........	144.50	" 0.15	21 68	0.000732
Sweeping..........	20	" 0.15	3 00	0.000101
Foreman..........	60	" 0.25	15 00	0.000505
	393.5			
MATERIAL.	QUANTITIES.			
Asphalt..........	25 230 lbs.	" 0.01225	309 07	0.010425
Haul..........	12.6 tons.	" 0.47	5 92	0.000199
Fuel..........	1.0 cord.	" 2.50	2 50	0.000084
Totals..........	....	....	$387 52	$0.013070
Contract price..........	....	....	$657 94	$0.022222

TABLE No. 6.—Cost of Filling with Mastic Crevices in Finished Brick Slope, 29 637 Sq. Ft.

Labor.	Total.		Total cost.	Total cost per square foot.
	Hours.	Rate.		
	146	At $0.15	$21 90	$0.000738
	130	" 0.15	19 50	0.000657
Attendance and sweeping........	56	" 0.15	8 40	0.000285
Foreman........................	30	" 0.25	7 50	0.000250
	362			
Material.	Quantities.			
Asphalt........................	2 813 lbs.	" 0.01225	34 46	0.001164
" haul.........................	1.4 tons.	" 0.47	0 66	0.000022
Fuel...........................	1.0 cord.	" 2.50	2 50	0.000084
Total cost.....................	....	....	$87 92	$0.003

Contractor's price included with coating.

TABLE No. 7.—Cost of Ironing Slope, 29 637 Sq. Ft.

Labor.	Total.		Total cost.	Total cost per square foot.
	Hours.	Rate.		
Ironers........................	29.55	At $0.15	$44 33	$0.001496
Heaters........................	75	" 0.15	11 25	0.000380
Sweeping and attendance........	34.5	" 0.15	5 18	0.000174
Foreman........................	49.5	" 0.25	12 37	0.000418
	454.5			
Material.	Quantities.			
Irons..........................	20	" 1.50	30 00	0.001012
Fuel...........................	1.0 cord	" 2.50	2 50	0.000084
Total cost.....................	....	....	$105 63	$0.003564

Contractor's price included with coating.

TABLE No. 8.—COST OF THE RESERVOIR. CAPACITY, 6 203 000 GALLS.

ITEMS.	Amount.	Total contract price.	Total cost to contractor.	Additional cost to city.	Total actual cost.
Excavation	49 540 cu. yds.	$7 431 00	$8 371 99	....	$8 371 99
Concrete on slope	603.3 " "	2 111 55	1 816 19	$1 702 75	3 518 94
" " bottom	678.2 " "	2 373 70	1 761 83	1 790 95	3 552 78
" in pedestal	18.0 " "	63 00	69 11	44 10	113 21
" " tunnel	12 6 " "	44 10	34 41	30 87	65 28
Cement coating, bottom	341.54 squares	....	129 63	254 80	384 43
" " pedestal	3.00 "	....	4 07	2 45	6 52
1st coat asphalt slope	29 637.0 sq. ft.	657 94	298 10	....	298 10
2d " " "	29 637.0 " "	657 94	387 52	....	387 52
1st " " bottom	34 454.0 " "	765 58	264 55	....	264 55
2d " " "	34 154.0 " "	758 90	280 79	....	280 79
Brick lining	132 0 M	2 500 50	2 633 49	....	2 633 49
Mastic on brick lining	29 637.0 sq. ft.	....	87 92	....	87 92
Ironing slope	29 637.0 " "	....	105 63	....	105 63
Parapet wall	289.0 cu. yds.	1 445 00	1 304 73	475 58	1 780 31
Iron fence	917.2 lin. ft.	....	....	985 40	985 40
Riprapping bank	....	....	....	36 23	36 23
Fixing road	....	....	....	17 40	17 40
Cleaning up	....	....	59 82	....	59 82
Grading around reservoir	800.0 cu. yds.	120 00	85 00	....	85 00
Office buildings, etc.	....	....	64 18	....	64 18
Water supply and main	....	....	288 00	....	288 00
Total	....	$18 929 21	$18 046 96	$5 340 53	$23 387 49

TABLE No. 9.—COST OF TUNNEL.

ITEMS.	Quantities.	Total cost to contractors.	Total contract price.	Additional cost to city.
Earth excavation	963.5 cu. yds.	$1 795 43	$963 50	
Timbering	....	587 38	837 00	
Earth excavation, north approach	157.0 cu. yds.	37 00	157 00	
Earth excavation, south approach	....	120 57		
Cleaning and relagging	....	16 50		
Rock excavation	296.7 cu. yds.	3 230 68	519 23	
Concrete lining	563.5 "	2 252 27	3 381 00	$1 161 30
Total cost	....	$8 039 83	$5 857 73	$1 161 30

DISCUSSION.

Mr. Hering.

RUDOLPH HERING, M. Am. Soc. C. E.—A commendable feature of the work described in the paper is the high degree of thoroughness that was not only proposed but apparently attained in all the important details. It is also to be commended that an accurate test was made of the leakage of the reservoir and the carrying capacity of the pipe line before they had been brought into use, which, unfortunately, is not always done. Owing to these early measurements, it will be a simple manner to observe any gradual change in the capacity of the pipe and to indicate the true causes for it.

It is interesting to see the comparative results obtained in the flow through wooden stave and steel pipes. The Kutter coefficient found from the former by experiment, namely, $n = 0.00985$, is less than that obtained by the Darcy-Bazin formula in a semi-circular channel of planed boards nearly 5 ft. in diameter, which is about $n = 0.0118$; but it equals almost exactly their result obtained in a small rectangular channel, 4 ins. wide, where it is $n = 0.0097$. When a high degree of smoothness exists in small channels or pipes, the coefficient varies much more rapidly than in rough channels; that is, a very slight change in the character of the surface makes a material difference in the flow. It is therefore especially important in such cases to have an actual measurement if possible, and not to depend solely upon formulas for very close results.

The steel plates were apparently made of sheets 4 ft. in length. These plates were No. 10 and No. 12, B. W. G., and therefore 0.134 and 0.109 in. in thickness, and were riveted with lapped joints in alternating large and small courses, the latter having the full nominal diameter of the pipe. Every eighth course was made slightly conical. Straight seams were double riveted, and round seams single riveted. For this pipe the Kutter coefficient was found to be $n = 0.0111$. Hamilton Smith, Jr., M. Am. Soc. C. E., obtained for riveted pipe of similar diameter and thickness of plate $n = 0.010$ to 0.011. The greater friction in the steel pipe than in the wooden stave pipe is undoubtedly due to the projecting plates at the joints and to the rivet heads. The smoothness of the surface of the two materials does not differ much.

The importance of the projections due to the thickness of the plates, as affecting the resistance, and as represented by the Kutter coefficient n, is again shown by this new gauging. Here the projections are 0.134 and 0.109 in., and n is found to be 0.0111. In the East Jersey Water Company's pipe, about 4 ft. in diameter, the projections are 0.25 to 0.375 in., and n averages 0.0148. In the wrought-iron riveted flume at Holyoke, Mass., about 8½ ft. in diameter, the projections are 0.36 in., and n equals 0.016.

The speaker was glad to see the continued use of stave pipe advocated, because it was certainly, at least for the Pacific coast, an excellent construction. It seems to outlast steel and iron, from the fact that the pressure of water from the interior causes the pipe to be continually saturated, and this seems to preserve it from rot, which is not the case with wood under other conditions. For that reason it has been suggested on the Pacific coast not to coat the pipe either inside or outside. It has been found there that if the stave pipes were coated on either or both sides they were more apt to rot than if they were left in a natural condition, because the coating would prevent the water from penetrating the wood as freely as necessary. It was assumed in a case that the speaker was familiar with, that such uncoated stave pipes would last at least twenty-five or thirty years, but no actual experience has, of course, been had with it for that length of time. Mr. Hering.

In referring to the asphalt lining of the reservoir, the speaker approved of the author's reasoning, having been careful to base his recommendations on the very latest results arrived at on the Pacific coast, where a number of asphalt-lined reservoirs of many different constructions have been built. For the slopes, where the trouble usually occurs, the author's recommendation was probably the best for the purpose, and one likely to give satisfaction also in the East, namely, first giving a coating of asphalt, then placing a layer of bricks laid flat upon it after they have been dipped in asphalt, and finally putting on another coating to fill up the joints. A very thin coat of asphalt or asphalt-concrete also appears to be satisfactory in similar cases. The brick lining was recently adopted as the best lining for the slopes of the Queen Lane Reservoir in Philadelphia.

CORRESPONDENCE.

EDMUND B. WESTON, M. Am. Soc. C. E.—As the writer has advocated the use of Darcy's formula,* he is pleased to see the close agreement between the experimental results given in the paper for the 16-in. steel pipe, and results that he has computed by Darcy's formula. The latter would give, considering the discharge and length given by the author (6.369 and 1 000), a loss of head due to friction of 5.1291, instead of the experimental result 5.0023, or about 2.5% more; and taking into account the friction head and length given by the author (5.0023 and 1 000), the formula would give a discharge of 6.2898 instead of the experimental result 6.369, or about 1.25% less. As will be seen by these figures, there is but a very slight difference between the results obtained by Darcy's formula and the experimental results, and the variation is upon the safe side. Mr. Weston.

* *Transactions*, Vol. xxii, p. 1.

Mr. Russell. S. BENT RUSSELL, M. Am. Soc. C. E.—The kind of reservoir lining used at Astoria may properly be compared with the lining used for the bottom of the new settling basins at St. Louis. There are six of these basins each 670 ft. by 400 ft., and from $11\frac{1}{2}$ to 18 ft. in depth of water when full. They have been in continuous use for over a year. The floor of these basins consists of 18 ins. of clay puddle protected by 6 ins. of concrete, which was laid in blocks 7 ft. square, with a $\frac{1}{2}$-in. joint. These joints were filled with a composition of equal parts of No. 6 paving pitch and powdered carbonate of lime. This composition becomes quite soft under the summer sun, but is always somewhat hard when submerged.

The basins are surrounded by heavy masonry walls, which rest on compressible earth. Since completion the walls have settled considerably, several inches in some places. This sinking of the walls seems to result in distortion of the adjoining bottom, as the blocks nearest the walls are found to have settled, and in some places they are cracked. Where the floor block has settled much, the pitch joint 7 ft. from the wall is found to have opened. Away from the walls, and usually adjoining walls that have not settled, the floor lining has proved a success so far. The joint filling rises when the blocks are warm and goes back when they are cool, as described by the author. The floor lining seems to have adjusted itself perfectly to all ordinary inequalities of settlement.

These basins will probably be repaired by taking up the floor blocks that have settled badly, and replacing them with blocks 7 ft. by 2 ft. and 8 ins. deep, laid with their major axis parallel to the wall. The joints will be filled with a somewhat stiffer composition, probably equal parts of No. 6 paving pitch, carbonate of lime, and clean, dry river sand. It is thought that the narrower blocks and greater number of joints will provide for all further settlement that may take place.

In operation these basins are drained and cleaned four or five times a year, and the bottom is thus exposed to more severe treatment than is the bottom of an ordinary service reservoir.

From this experience, the writer is inclined to fear that floor blocks 20 ft. square, as described in the paper, might prove a failure on ground at all unstable. It seems questionable, too, whether the coating of asphalt on top of the blocks would be much protection in case of broken blocks or distorted joints. As the coating adheres to the top of the floor block, the strain on the coating would be concentrated over the joint or crack, and the continuity of the coating would be greatly endangered. These suggestions are based on the assumption that the pitch composition and asphalt act in much the same way, as would seem probable from the nature of the two materials.

Mr. Harlow. JAMES H. HARLOW, M. Am. Soc. C. E.—The writer's experience leads him to doubt the correctness of the views expressed in the following quotation from the paper:

Mr. Harlow.

"The author holds in the much-discussed question to which this gives rise, that though a private person or company may often with creditable discretion discard a bid that is too low, yet in handling the funds of a municipality, if the proposal is strictly formal, and the securities satisfactory, the administrator of such funds cannot, with due propriety and proper regard for the wishes of the public whom it serves, discard such a bid."

The writer cannot see how it is more creditable for a municipality to obtain something for nothing, or something for less than its value, than for a private individual. The contractor may make a mistake in his bid for any given work, but when this mistake is self-evident, such bids should be rejected. An engineer can be more lenient in the enforcement of the detail specifications when the contractor is making money. If the contractor is losing money, he urges with a good deal of force that leniency granted on one point should be granted on other points where the engineer should carry out the exact wording of the specifications.

An example is afforded by the case of a borough in the vicinity of Pittsburg, where about ten years ago the municipality decided to construct water-works. The borough's engineer prepared the necessary specifications and plans, and bids were asked for. The proposition of the lowest bidder was from a party who had considerable previous experience in the construction of railroad embankments and culverts. He was a rather ignorant man, with no experience on work similar to that on which he had now bid. The second lowest bidder was a man with much experience in the construction of water-works, and whose bid was about $4 000 above that of the lowest bidder. As to the financial responsibility, the second party stood better. Both parties were able to give suitable bonds.

The engineer reported against awarding the contract to the lowest bidder, his argument being that the bid was entirely too low. The Borough Council decided to award it to the lowest bidder, believing that in case of loss it would not fall upon the borough, for it had sufficient bonds to compel the construction of the works as designed. After the award of the contract, and after the contractor had been working some weeks, the work began to drag. Complaints were heard that the work was not properly managed, and the laborers were not being paid the full amounts due them; and soon it became necessary to forfeit the contract, and the bondsmen were called upon to complete the work. This they did. The report is, that the bondsmen divided up the cost of several thousand dollars between them. So far as the borough was concerned, the work was completed, and to the satisfaction of the engineer and other officials.

Several of the bondsmen lived in this borough. One of them was crippled in his business by the withdrawal of his share of the expense on account of the contract; the result was that he failed. Accord-

Mr. Harlow. ing to newspaper reports, labor bills to the amount of some $1 500 were outstanding, and attempts were made to collect from the borough, and, finding this could not be done, an attempt was then made on the bondsmen. The writer does not know exactly how this point was settled, but his impression is that these laborers never received their money, the bondsmen claiming that while they were responsible to the borough for the satisfactory completion of the work, they were not responsible to the laborers or for material furnished the contractor prior to their assumption of the work. A number of these laborers were residents of the borough.

Some two or three years after this, the writer was called upon to design a water supply system for the adjacent borough, and during his investigations there became acquainted with a number of men who had furnished material to the contractor mentioned previously. These claims had never been settled. They varied from $800 for cement down to $75 and $50 for sand and other materials. The aggregate of the bills that the writer found was something in the neighborhood of $2 500. These material men resided in the borough.

It has always been a question to the writer whether the borough was justified in the awarding of this contract to the party it did, remembering that the borough is made up of individuals, and a number of these individuals had to pay the difference in the cost.

The author says that "by a combination of circumstances, fortunate to the city, the works have been completed at a remarkably small cost." From what precedes this item, has not a considerable difference been paid, not by the city as a city, but by individual and innocent inhabitants of the city? This is apparently the fact, for the reason that the city apparently paid something over $4 500 in excess of the contract price for the reservoir.

Mr. Gould. E. Sherman Gould, M. Am. Soc. C. E.—The gaugings on page 4 show a steady diminution in the minimum flow during the four years of observations. In 1893 the flow above the mouth of Cedar Creek was 2 646 000 galls. per 24 hours, and in Cedar Creek 718 000 galls. per 24 hours. These two flows combined, as the writer understands it, would be the amount furnished by the stream at the point of diversion, and would aggregate 3 364 000 galls. per 24 hours. This is not an encouraging outlook for a supply of 4 000 000 galls. per 24 hours, with a storage of only 50 000 000 galls., or only enough for about 12 days' consumption.

All that is said about the wooden pipe is of great importance. This kind of conduit can evidently be used only under light pressures, say 100 lbs. per square inch as a maximum. This materially limits its availability. It is to be regretted that more details, with a longitudinal section through the joints, were not given of the steel pipe, which seems to be of a somewhat unusual type.

The increased flow in the wooden pipes was to be looked for, owing

to the greater regularity of its interior surface. Had a steel pipe been used in its place, with the given grade, a diameter of about 19 ins. would have been required, so the gain is only about 5% in favor of the wood. A query naturally arises as to the diameter of the wooden pipe being strictly 18 ins. It must be difficult to ascertain the exact working diameter of such a pipe. The hydraulic grade line of the steel pipe seems to have been less satisfactorily determined than that of the wooden one, for, on account of its greater height above the pipe line, no stand pipes were placed upon it. Taking the data as given by the author, the flow is large for a pipe of that character and diameter. Here, too, there must be some difficulty as to true diameter, because, for one thing, the longitudinal lap joint in so small a pipe is a confusing element. Mr. Gould.

The proportions of the concrete seem to have been in round numbers, 1 cement, 0.8 sand, 4 gravel and 7 broken stone. This seems a rather lean mixture for hydraulic work, but the cement being good Portland, there is no doubt that, with careful mixing and placing, satisfactory results could be confidently anticipated. It is stated that 1 558 barrels were used to make 1 282 cu. yds. of concrete. This makes, including plastering and waste, nearly $1\frac{1}{4}$ barrels per cubic yard, which represents good, honest work under the above proportions. The quantity put in per day on the bottom, 2.35 cu. yds. per man, if by per man "all told" is meant, is a very high average and represents smart work.

Were the joints really "expansion" joints; that is, did the asphalt filling them compress and dilate after the fashion of india-rubber? If the underlying concrete contracted and expanded, what effect did this movement have upon the sheet of asphalt spread over the surface? To the writer's mind, one of the great advantages of concrete consists of its being used in a continuous mass. When building the Palatino Reservoir at Havana, Cuba, a few years ago, he had occasion to use concrete as a bottom lining upon a fairly large scale. This was a double reservoir, the bottom surface of each compartment being of about 60 000 sq. ft. The thickness of the layer of concrete was about 1 ft. Imported Portland cement was used, the proportion being one part of cement, three of sand, and six of broken stone. The sheet was spread continuously without joints, and never showed signs of any material movement. The work was of the best character, and the finished concrete kept constantly moist for a long time—perhaps a week or two, or even longer—after being laid. Constant wetting of all masonry was insisted upon. After a month or two the concrete resisted the action of a sharp pick. It is true that the range of temperature to which it was exposed was probably much smaller than at Astoria, but the result was so perfect in every respect that the writer would need strong proof to convince him of the expediency of foregoing the great advantage of keeping his floor absolutely continuous.

Mr. Riffle. FRANKLIN RIFFLE, M. Am. Soc. C. E.—In defending the action of the Water Commission in awarding the contract for divisions 1, 2, 3 and 7 to the lowest bidder, the author makes the following explanatory statements:

First.—The proposal was "formal in the last degree."

Second.—The contractor was "determined to have his rights recognized at any cost."

Third.—Although "a private person or company may often, with creditable discretion, discard a bid that is too low, the administrator of public funds cannot with due propriety and proper regard for the wishes of the public * * * discard such a bid."

The first two statements convey the impression that the contractor's "rights" called so loudly for recognition that the Commission was legally powerless to exercise any discretion in the matter. The writer, being acquainted with the facts, is of the opinion that the contractor had no rights to enforce, either legal or moral. He had become hopelessly involved in a paving contract in a neighboring city only a few months before, and deemed it expedient, prior to submitting a proposal at Astoria, to incorporate under a new name. The engineer had, with commendable foresight, introduced into his specifications the following provisos, which are singularly applicable to the case in hand:

"The Water Commission reserves the right to reject any or all bids, or parts of bids, which they may not deem advantageous to the city."

"No proposal will be accepted from any firm or person known either to the Commission or the engineer to be in arrears on other contracts, or to have failed in other contracts to comply with the specifications, and fulfill his contracts."

Just why these excellent stipulations were waived by the Commission is not apparent, unless the explanation be found in the author's last statement. Here he virtually takes the untenable position that conservative business methods cannot with propriety be employed in the administration of public affairs. He assumes that such a procedure is contrary to "the wishes of the public." The defence becomes weaker still when it is considered that the Astoria Water Commission was composed of representative business men, and was clothed by the State legislature with large discretionary powers. The practice of indiscriminately awarding contracts to the lowest bidder promotes incompetency and rascality. In the case under discussion the contractor, having nothing to lose, could well afford to take chances which a responsible contractor dare not take. So long as he could satisfy his creditors with partial payments he would be able to appropriate a good portion of each monthly payment received from the city to his individual use. This was actually done. In the end he was better off financially than if he had failed to secure the contract.

It is to the engineer, rather than the average municipal board or commission, that one would naturally look to advocate the rejection

of undesirable bids. He is presumed to know the difficulty of obtaining good results when the contractor is losing money, to say nothing of the probability of vexatious and expensive complications, which may entail a serious loss upon the city. The writer holds, therefore, that it should be the duty of the engineer of either a public or private enterprise to determine which one of the several bids received is the lowest and the best, and to urge its acceptance without fear or favor. Mr. Riffle.

The location of the pipe line was evidently made with great care, and the result certainly justifies the painstaking methods employed. In a country such as that described by the author a carefully surveyed preliminary line, supplemented by an accurate contour map, is almost an absolute necessity. Without it an intelligent, economical location is practically impossible.

The expense, however large, is fully justified. The advantage of a contour map as an aid to location is clearly pointed out in the author's statement that the length of the line as finally located is one mile shorter than the preliminary line, a saving in distance of about 10 per cent.

The location of the Astoria reservoir is known to the writer as having been made only after considerable investigation. At Astoria the hillsides in many places consist of unstable material, which has a tendency to slide when saturated with water during the rainy season. Excavations disturb the equilibrium of these hillsides to such an extent that the most serious consequences often ensue. The engineers who had charge of the construction of the Oregon Railway and Navigation Company's lines, and the Cascade Division of the Northern Pacific Railway were given much trouble by slides, and although these roads have been in operation for a number of years, each successive rainy season brings a recurrence of the evil. This feature of the hillsides of this section of the Pacific Coast is so thoroughly understood by most of its residents, that the construction of two of Portland's large reservoirs in a ravine, one side of which was clearly unstable, occasioned considerable comment. As was reasonably predicted the hillside began to slide before the completion of the work, and although eighteen months have elapsed since their completion, the reservoirs have been undergoing repairs during this period at a large expense. It is but fair to add that, although the construction was under the charge of one of the most prominent engineers of the Pacific Coast, he was in no way responsible for the selection of the sites.

The Astoria reservoir site was selected by the author about the same time as the Portland reservoirs were located. His attention being called soon after to the sliding character of the ground in the immediate vicinity, he began a thorough investigation which ended in the rejection of his first choice, and in the selection of a site in another portion of the city where there was no question as to stability. The

Mr. Riffle. author stated to the writer that in making the change he was guided by his own judgment, supplemented by the opinions of local men of intelligence who knew much more about the peculiarities of the country from long residence than he did. Such a spirit is highly commendable, and stands out in sharp contrast with the practice of engineers who consider it beneath their professional dignity to make use of knowledge obtained from what they choose to term humble sources.

The writer does not believe that the publication of the cost of work in detail, as has been attempted by the author, is attended with beneficial results. While engineers of experience fully appreciate the fact that local conditions must be taken into consideration in applying the cost figures obtained in any locality to another locality, incompetent and inexperienced engineers are very apt to be misled by such figures. It must also be borne in mind that the bare cost of labor is but one item in the cost of work to the contractor, and although it is usually the largest item, it often falls far short of the total cost. Office and traveling expenses, freight charges, depreciation of plant, etc., are items that oftentimes assume large proportions, and are strictly chargeable to the cost of the work. Without these items, tables such as those included in the paper under discussion, are misleading for the purpose of estimating the cost of work. While an experienced engineer would undoubtedly add a liberal percentage for items not included in the tables, an incompetent engineer would unhesitatingly appropriate them verbatim.

Mr. Henny. DAVID C. HENNY, M. Am. Soc. C. E.—In describing the details of the Astoria stave pipe, the author calls attention to the difficulty experienced in obtaining fir staves of a quality suitable for pipe construction. Douglas fir is a very superior wood in respect to strength, stiffness and straightness of grain, and has the further advantage of being cheap and readily obtainable in large quantities free from knots. Yet it possesses qualities which render it less desirable for use in stave pipe than would at first appear. It is subject to considerable shrinkage and checking, which is of importance when finished staves are to be shipped and hauled long distances and left exposed some time along the pipe trench. It was a fortunate circumstance in Astoria that the pipe line runs for its entire length through the thick woods, where the staves were protected from the sun and wind.

Another disadvantage of fir is that its grain is not so close as that of other woods, such as cypress and redwood, necessitating great care in the selection of the staves used in heavy pressure pipe, to prevent percolation. The principal disadvantage is, however, that pitch seams are so common that a certain percentage is permitted, even in the ordinary clear grade as occurring in the market, and that to obtain fir absolutely free from pitch seams requires a weeding-out process from beginning to end, very discouraging to the proprietor of the mill, and

most difficult to carry through without compromise. A pitch seam is caused by the accumulation of pitch between two annular rings; therefore it is not necessarily objectionable in a bastard grain stave, unless too large. In a quarter-sawed stave a pitch seam showing on both sides is sure to cause a leak. If it shows on one side only, and penetrates but little, no leakage would result from it; but the depth of penetration cannot be definitely ascertained, except by sawing the piece in two. Of two pitch seams, similar in appearance and permitting the insertion of a knife point to the same depth, one will often be found to be shallow and the other to go nearly through. Mr. Henny.

Rigid requirements and inspection of the wood necessarily lead to a higher price of the pipe, to which there is, with some engineers, a dangerous tendency to object, seemingly from a desire to make the saving resulting from the use of stave pipe unduly large.

The specifications under which the Astoria wooden pipe was built prescribe in detail the character of all materials to be used, as well as their quantities and dimensions, and provide that all work shall be done in a manner satisfactory to the engineer. Finally there occurs in the specifications the following clause:

"In the erection and filling of pipe great care must be exercised by the contractor to prevent overstraining of the bands. The final test of the satisfactory fulfillment of the above requirements shall be that no band on being removed from the pipe, after the latter has been subjected to its natural working pressure for at least thirty consecutive days, shall show any appreciable fixed increase in its original length; and the failure of 5% of the bands examined to meet this requirement, shall be deemed sufficient grounds for the rejection of the entire work, until such defects have been entirely repaired in a manner satisfactory to the engineer."

It will be observed from this, that after the contractor shall have furnished the materials and performed the work in all respects as required by the engineer, he is still liable to have his entire work rejected although the pipe line should prove to be entirely tight.

The experiments mentioned by the author on page 18 were undertaken to determine the extent of the risk involved. The results were satisfactory, in that they indicate that the highest strain that could be produced by continued cinching of the band on the kiln-dried section of pipe is well within the elastic limit of the steel, and that there is a tendency for this strain to drop back speedily to the safe limit of about one-fourth the ultimate strength of the bands. This is due rather to a yielding of the fiber under the round band than to lack of compressive strength of the wood in the direction of its width. It should be understood that a wooden pipe, when properly built, has its bands cinched and hammered into the wood until a width of bearing is procured about equal to the radius of the band, which may be done without injuring the fiber.

A lineal inch of a ½-in. band, as was used in the experiment, has a

Mr. Henny. bearing on the wood of about ¼ sq. in. A strain on the band of 4 750 lbs. indicates a pressure per lineal inch of band on the wood of 458 lbs., or about 1 832 lbs. per square inch of bearing, which, as might have been expected, could not be permanently sustained by water-soaked fir, regardless of the simultaneous tendency of the wood to swell, and this sufficiently accounts for the gradual reduction of the strain as recorded.

The limit of compressive strength of the staves in the direction of their width was not reached in any of the experiments mentioned; and hence the author's conclusions on this point and on the consequent limit of safe pressure in wooden pipe construction are believed to be very conservative.

The author states that yellow fir is a hard and rather unyielding material. This statement is probably intended to apply to the wood when perfectly dry, for the writer has found that fir, when partly green, can be readily compressed, as was proved in the cinching of the Astoria pipe. The cinching is intended to be carried on to a point where the width of the stave is forcibly reduced to a lesser width than would have resulted from shrinkage in drying, and this could be accomplished where the banding was close. Where the bands are spaced far apart, continued indentation of the band rather than further reduction of the width of the stave results. Light-banded pipe, if it is to be tight upon first filling, should be back-filled immediately after cinching, or, if not to be covered, should be recinched just before filling.

The author states that the wooden pipe at Astoria was entirely tight from the beginning, and that this is contrary to the usual experience with stave pipe. While such absolute tightness at first filling as was here attained may be exceptional, the writer believes it to be entirely within the bounds of skilful workmanship and inspection to avoid from the start practically all causes of leakage.

The author's measurements of the actual amount of leakage of the Astoria conduit are very instructive, especially as they illustrate the comparative tightness of the wooden and the steel pipe in this instance. They are of the more value because the opportunity of taking accurate measurements of leakage of pipe lines is usually either lacking or allowed to remain unimproved.

In determining upon a diameter of 18 ins. for wooden pipe, the author had in view the advantage of rendering the inside of the pipe accessible for purposes of construction and inspection. As final inspection is done from the outside, the main advantage lies in the ease of rounding the pipe out from the inside. In this connection it may be stated that in his recent practice the writer has used, on pipe smaller than 18 ins., rounding-out machines, of simple construction, inserted in the pipe and operated from its open end, which perform their work as perfectly as can be done by an inside man with a mallet. While

Mr. Henny.

the constructional advantage is the only reason advanced for the difference in the diameters of the wooden and the steel pipe, it appears that the author has incidentally put into practice the economical principle in the design of long pipe lines with greatly varying pressures, which demands the saving of available head on the cheaper or light pressure portions of the line and its concentration upon the more expensive or heavy pressure portions, and it is believed that an actual saving has resulted in this case from the adoption of a broken grade line.

The author's experiments on frictional loss are a welcome and needed addition to engineering knowledge, valuable especially on account of the accuracy with which both the hydraulic grade line and the flow have been ascertained. The close agreement between the assumed and the measured hydraulic grade lines is remarkable. The coefficient of roughness of 0.01 usually assumed for wooden stave pipe is shown in this case to have been slightly in error on the safe side. It may be appropriate to state here that on the wooden pipe line at Astoria there are, in addition to a succession of sweeping horizontal and vertical curves, twenty-seven cast-iron bends, with a radius of curvature of 5 ft., and with an average central angle of about 31°, conditions more unfavorable than are usually met with.

The reservoir at Astoria is located on the top of a knoll on the side of a range of hills away from the Columbia River and the city. If this location was selected to guard against danger of landslides, which, owing to the geological formation in connection with the copious rainfall during the winter season, are rather common in the northwestern portion of Oregon, the extra expense of a tunnel, which is necessitated, was most wisely incurred. Experience with two new reservoirs in a neighboring city, completed since the location of the Astoria reservoir was decided upon, indicates that neither extreme care in construction nor the exercise of every practicable precaution in strengthening the lining or sub-draining the slopes is adequate to prevent failure of a reservoir built in sliding ground.

It has become rather customary on the Pacific Coast to make water power development an incidental part of work in connection with gravity pipe lines originally intended for domestic supply only. The writer questions the wisdom of this, in some cases, and believes that the difference in cost of the work with and without this addition is not always ascertained, and a comparison of the resulting cost of water power with that of steam power is often deemed superfluous. He mentions this, not because of a doubt that such comparison has been made in this instance and the extra outlay has seemed justifiable, but because comparative figures would be interesting, especially considering the cheapness of fuel in Astoria.

The detailed statements of the actual cost of portions of the work add materially to the value of the paper. As they are based, however, on the reports of timekeepers, and in the nature of the case cannot

Mr. Henny. take into account the many miscellaneous and unavoidable expenses of the contractor, which at times exceed the percentage ordinarily estimated by the engineer for contractor's profit, they necessarily understate the real cost of the work by an unknown amount, and if made the basis for future estimates it is evident that their use cannot dispense with experience and good judgment.

Mr. Adams. ARTHUR L. ADAMS, M. Am. Soc. C. E.—The author is pleased that the action of expansion joints in concrete construction, as described in connection with the Astoria reservoir, has been verified by Mr. Russell in his observation of somewhat similar joints in the St. Louis settling basins, especially since Mr. Gould seriously questions that the joints act as described. The purpose of the joints in the reservoir bottom was to prevent temperature cracking rather than to anticipate any considerable settlement, and for this purpose a joint every 20 ft. seems sufficient. The thin coating of asphalt applied to the finished bottom concrete is intended as an additional safeguard against cracking from a similar cause, besides rendering the bottom less pervious to water. Such a coating cannot be expected to maintain its continuity in case of very serious breaking up of the underlying concrete. A course of brick dipped in asphalt and laid on top of the concrete, as was done on the slopes, would doubtless prove much more effective under trying conditions. The author is much interested to learn through Mr. Hering's comments that the slopes of the Queen Lane Reservoir at Philadelphia are to be treated in a manner similar to the Astoria work, especially as he knows that the engineers charged with the former work have given much time to the investigation of different types of asphalt linings, and have doubtless had to do much sifting in the determination of the actual facts relating to the matter.

Regarding the proportions used in making the concrete, the writer is not disposed to agree with Mr. Gould in pronouncing the composition a lean mixture. The apparent scarcity of sand has been accounted for by the presence of a large amount in the gravel used. The size of this gravel varied from that of a pea to fine sand. The volume of the voids in the sand and gravel was carefully determined, and the requisite amount of cement thus ascertained. In reality, the proportion of sand to cement was little in excess of two to one. The resulting large saving in cement was accomplished by the use of gravel in addition to the broken stone, an economy overlooked by many engineers; and the proportion of cement to voids was doubtless greater than in the three-to-one mixture which Mr. Gould speaks of having used so successfully at Havana, Cuba. The resulting concrete was excellent in quality, and could be picked with the greatest difficulty after being in place ten days. The honesty of the contractor in the use of the cement was no doubt due to its being furnished by the city.

Mr. Gould's statement that the stave pipe shows but 5% advantage over the riveted pipe, because this amount of increase in the diameter

of a riveted pipe would give a carrying capacity equal to the stave pipe, seems rather unfair to the latter, since any increase in diameter renders necessary a proportional increase in the thickness of the metal also, if the same factor of safety is to be preserved. The ratios of their respective carrying capacities for similar diameters, as determined by use of the experimental value deduced for the factor n for each class of pipe, would express their real relation much more correctly, and in this case would show an advantage of 12% in favor of the stave pipe. Mr. Adams.

Mr. Henny calls attention to the probable economy resulting from the use of a broken hydraulic grade line instead of a uniform diameter of pipe. With steel pipe there may often be effected a considerable saving in this way when dealing with light pressures and pipes of moderate diameters, in which cases the requisite thickness of metal is determined by structural requirements rather than the pressure. Under these conditions an increase of diameter and an incidental saving in fall can be accomplished without increase in the thickness of the plate; and the head thus saved may be used, as Mr. Henny suggests, in decreasing the diameter where the pressure is the controlling factor in determining the thickness of the metal. Though true to a less degree than in the case of steel, wrought-iron or cast-iron pipes, this reasoning is also applicable to stave pipe and applies at Astoria.

The development of power from the pipe line was wholly incidental to the general design, which was controlled by other considerations, principally the desire to supply directly by gravity three of the four distributing services contemplated. The only additional expense incurred by the power appendage was due to the fittings and building necessary for its utilization.

There seems to be some difference of opinion between Mr. Riffle and Mr. Henny as to the value of published statements of cost of work in general, but there seems to be no disagreement regarding their value to those who know how to use them. It is therefore fortunate in the present instance that the tables of cost have been submitted to the American Society of Civil Engineers.

Mr. Riffle and Mr. Harlow both take strong exception to the author's defence of awarding contracts to the lowest bidder. Mr. Riffle's argument would in the case in hand be a very plausible one, were his premise, that "the contractor had no rights, either moral or legal, to enforce," a correct one. The very bad previous reputation which he gives the contracting company in question, based, he says, on personal knowledge, was, unfortunately for his argument, not borne out in the careful investigation made by the Astoria Water Commission previous to making the awards. In justice to the contractor in question, it may be said that these damaging facts proved to have very slight foundation when divested of the superstructure imposed by competing contractors. As a guarantee of the company's ability to furnish satisfactory sureties on its bonds, it had deposited with its

Mr. Adams. bid a certified check for $11 000, although the total amount of the contract awarded it aggregated but $50 000. Whatever the final outcome, it seems manifestly unfair to designate such a company as an irresponsible bidder; and the author, after carefully weighing all facts, was in accord with the Commission in determining that the company in question did not clearly belong in that category, and, as the lowest bidder, had rights that should be recognized. Had this bid been rejected under existing circumstances on the ground of irresponsibility of its signers, and the work awarded at a higher figure to other parties, the public as well as the disappointed contractor could very properly have demanded sound reasons for this repudiation of all that is implied in the advertising of work to be let to the lowest responsible bidder, and the requiring of certified checks, bonds, etc., as a guarantee of that responsibility. If, as Mr. Harlow favors, contractors are not to be awarded work because, regardless of security asked and offered, the engineer considers the bid too low, then the whole system of competitive bidding and of requiring guarantee bonds from the party to whom award is made, is but foolishness, since the requiring of security means nothing. Consistency will require those not satisfied with present methods of public contract letting to advocate radical fundamental changes, rather than to wish the logical sequences of those methods ignored, or to expect engineers in charge of work to make themselves unwelcome and self-constituted guardians of the private fortunes of contractors and their sureties who are so bold as to differ from them in their ideas relative to the probable cost of work. The author believes that the interests of contractors of unquestioned responsibility are best protected against men of doubtful standing by just such an unswerving, consistent course as that adopted by the Astoria Water Commission, by which means, without in any way jeopardizing the city's interests, a financially irresponsible contractor, should he prove to be such, would be speedily and permanently disposed of as a future competitor. At Astoria, thanks to the exercise of care in the acceptance of bondsmen, there were no expensive delays incident to the contractor's failure, and this part of the work was completed sooner, and on the whole with less trouble, than was the case with certain financially very responsible contractors on other parts of the work. The $4 500 "additional cost to the city" above that earned by the contractor on the reservoir was not, as Mr. Harlow suspects, used in settling unpaid bills of the contractor, but was the price paid for the cement used in the work.

Owing to the geological formation at Astoria, the unstable ground all lies upon the north or Columbia River side of the peninsula, while on the south or Youngs Bay side the material is of a wholly stable character. It was because of this condition that the reservoir was located on the south side, and the connection accordingly made with the distribution by means of the tunnel.